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1	23756	@ad<19991105 and (picture or photo$5) with (sensor or sense or trigger)	USPAT	2003/04/23 20:42
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3	19	@ad<19991105 and (picture or photo$5) with (sensor or sense or trigger) with (race or finish or competition)	USPAT	2003/04/23 21:00
4	17	@ad<19991105 and "photo-finish"	USPAT	2003/04/23 20:48
7	3370	@ad<19991105 and (transmitter or component or device or tag or label or mark or item) near5 (sense or sensor or track or monitor or trigger) with (picture or photo or photograph or snap or take)	USPAT	2003/04/23 20:56
8	18	@ad<19991105 and (transmitter or component or device or tag or label or mark or item) near5 (sense or sensor or track or monitor or trigger) with (picture or photo or photograph or snap or take) with (race or event or competition)	USPAT	2003/04/23 20:57
9	452	@ad<19991105 and (picture or photo$5).ab. and (sensor or sense or trigger) and (race or finish or competition)	USPAT	2003/04/23 21:02
10	59	@ad<19991105 and (picture or photo$5).ab. and (sensor or sense or trigger) with (camera) and (race or finish or competition)	USPAT	2003/04/23 21:03
11	19	@ad<19991105 and (picture or photo$5).ab. and (trigger) with (camera) and (race or finish or competition)	USPAT	2003/04/23 21:03

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Sigel et al.

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(54) **CAMERA WITH OBJECT RECOGNITION/ DATA OUTPUT**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(52) **U.S. Cl.** **348/157**; 348/169; 348/222.1

(58) **Field of Search** 348/135, 136, 348/137, 139, 140, 142, 143, 157, 159, 169–172, 207, 222, 222.1; 386/110, 117; 340/540; H04N 5/225, 7/18

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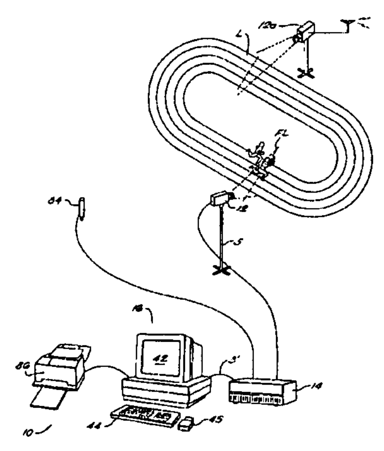
Primary Examiner—Ngoc-Yen Vu
(74) *Attorney, Agent, or Firm*—Lahive & Cockfield, LLP

(57) **ABSTRACT**

A line scan digital camera is directed at a station for recording and displaying a time-sequential scene. The digital camera takes a sequence of digital image frames representative of one or more bodies crossing a plane in space, wherein each frame represents a line image of the body, thus forming a fractional part of the scene, and the set of time-successive frames forms a recognizable image on an external display. Within the camera, frames enter a buffer and a microprocessor in the camera compares blocks from successive line images to detect changes indicative of objects entering or leaving the field of view. The changes detected by pixel or block analysis identify information-containing portions of the data stream and their time of occurrence. When the start or end of an object is detected the microprocessor flags the image stream with the detected data to produce an image data stream which can be more readily received and used by the external race management system, or the processor operates a controller in the camera which passes the active portion of the image information data stream to the output port, producing a more compact data stream with no loss of information. In a preferred embodiment, the camera is an event camera at a competition, and it images the finish line or an intermediate station to determine crossing times of contestants. Preferably, the microprocessor further detects optical patterns in the image so formed, such as bar code, numeric, or special marking features to identify contestants, or detects body features to determine estimated crossing times or other photocell determinations. This substantially automates the provision of race results, and allows relevant finish line pictures to be immediately presented to the judges from the raw image frames. The camera is also adapted to robotic vision applications for stations at irregular transport lines, and for mid-course identification and reporting along race tracks, transport lines and traffic environments.

20 Claims, 6 Drawing Sheets



passive component

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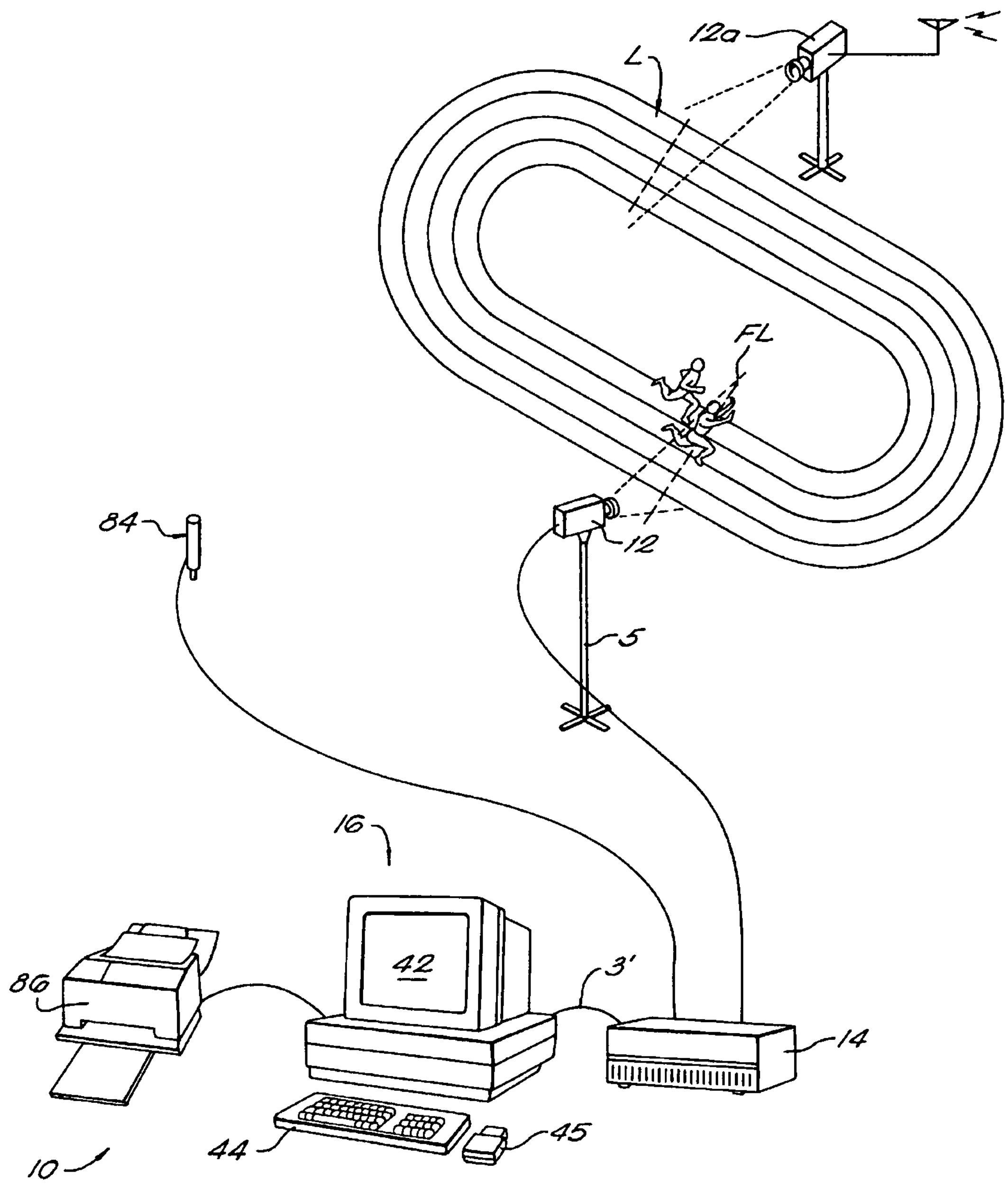


FIG. 1

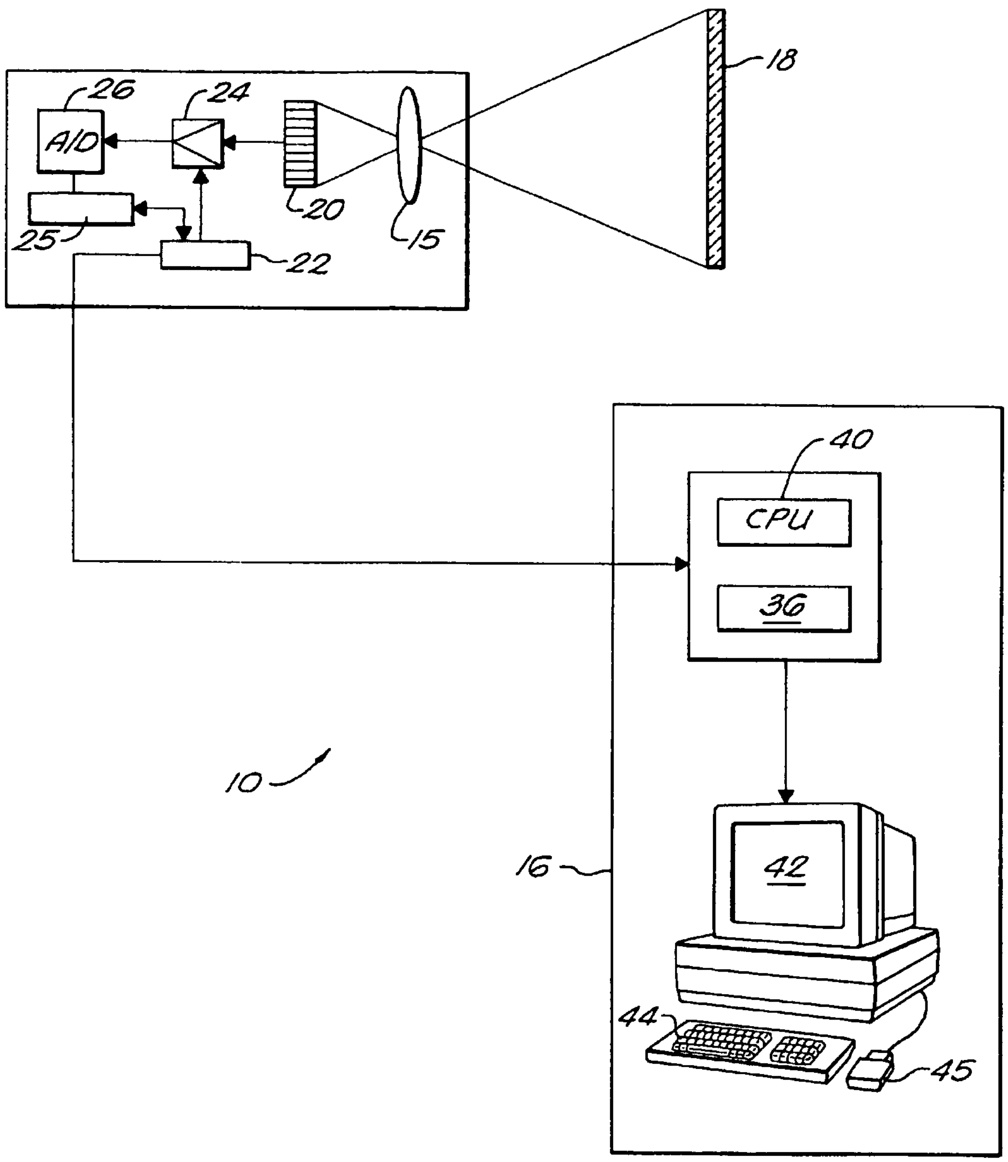


FIG. 1A

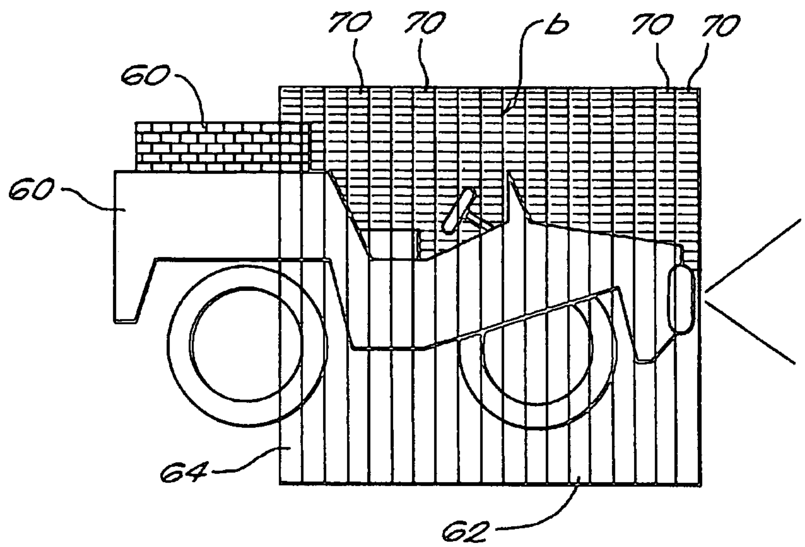


FIG. 2

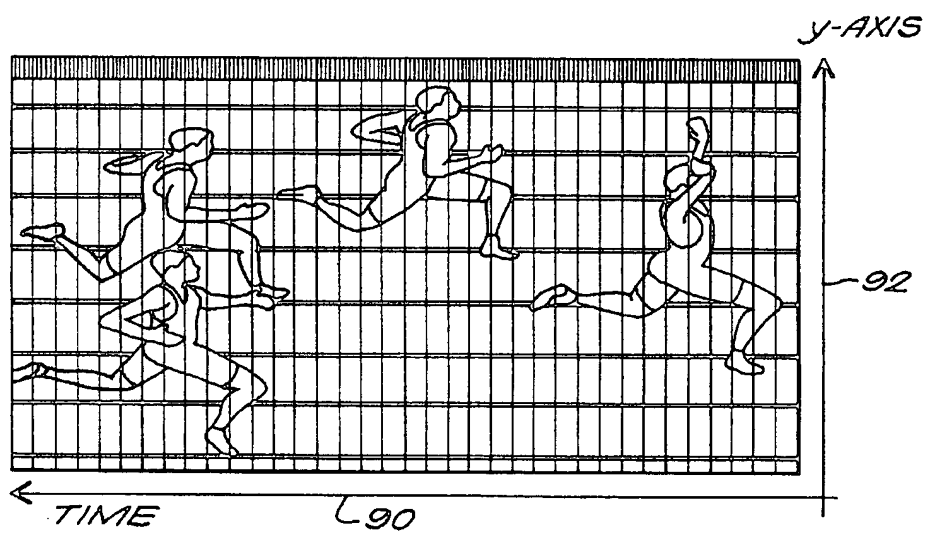


FIG. 3

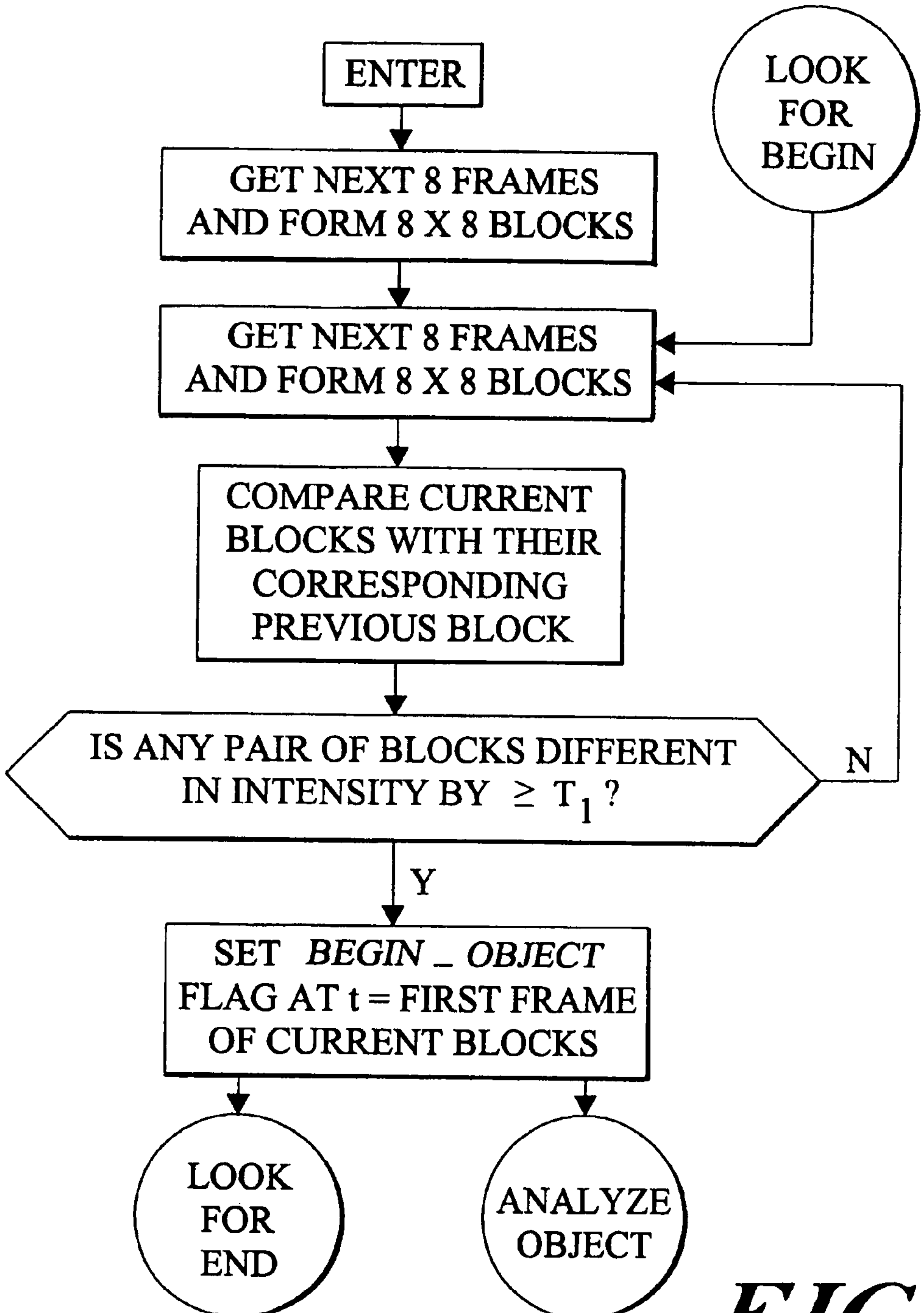
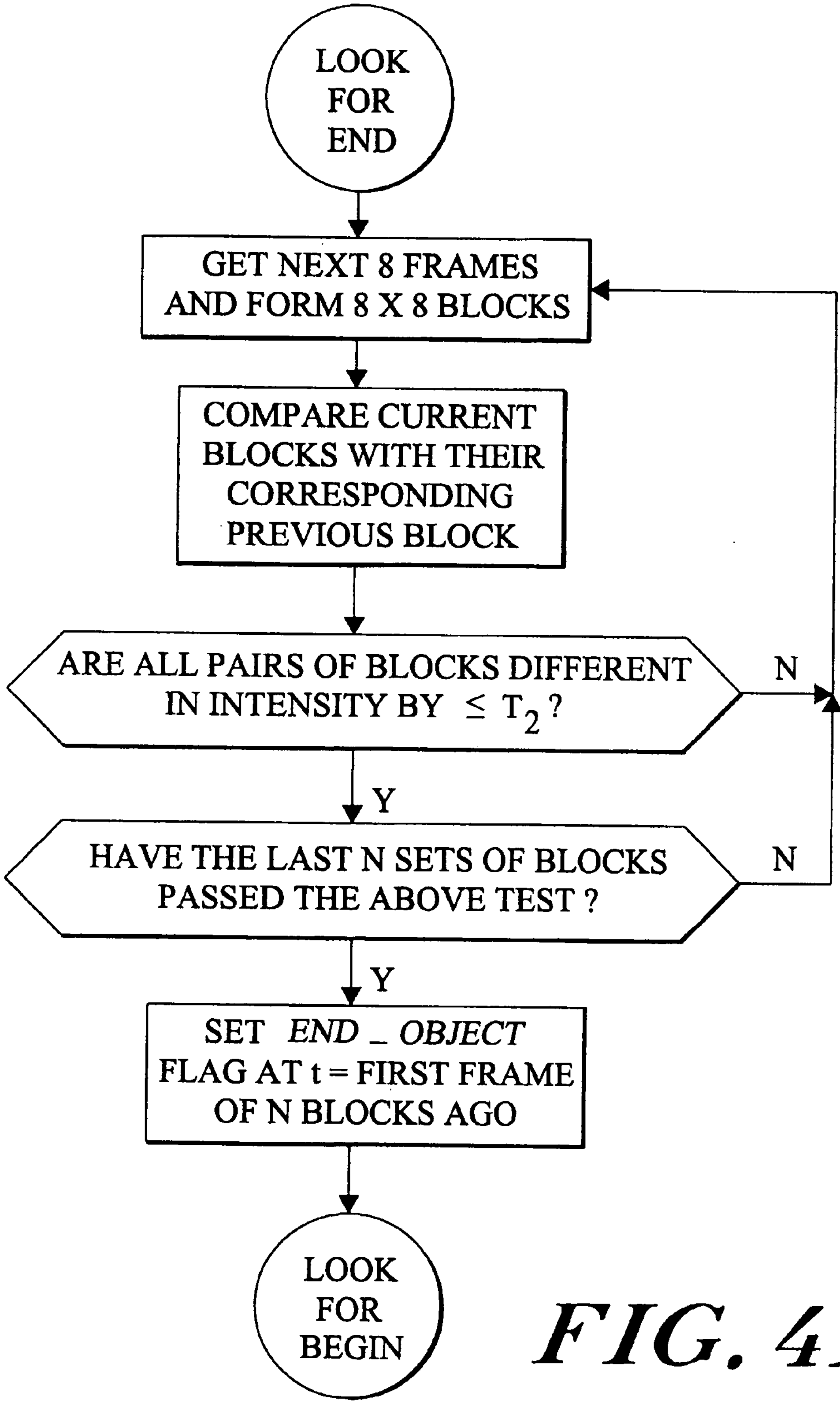

ENTER
LOOK FOR BEGIN
GET NEXT 8 FRAMES AND FORM 8 X 8 BLOCKS
GET NEXT 8 FRAMES AND FORM 8 X 8 BLOCKS
COMPARE CURRENT BLOCKS WITH THEIR CORRESPONDING PREVIOUS BLOCK
IS ANY PAIR OF BLOCKS DIFFERENT IN INTENSITY BY ≥ T_1 ?
N
Y
SET *BEGIN_OBJECT* FLAG AT t = FIRST FRAME OF CURRENT BLOCKS
LOOK FOR END
ANALYZE OBJECT

FIG. 4



LOOK FOR END
GET NEXT 8 FRAMES AND FORM 8 X 8 BLOCKS
COMPARE CURRENT BLOCKS WITH THEIR CORRESPONDING PREVIOUS BLOCK
ARE ALL PAIRS OF BLOCKS DIFFERENT IN INTENSITY BY $\leq T_2$?
N
Y
HAVE THE LAST N SETS OF BLOCKS PASSED THE ABOVE TEST ?
N
Y
SET *END _ OBJECT* FLAG AT t = FIRST FRAME OF N BLOCKS AGO
LOOK FOR BEGIN

FIG. 4A

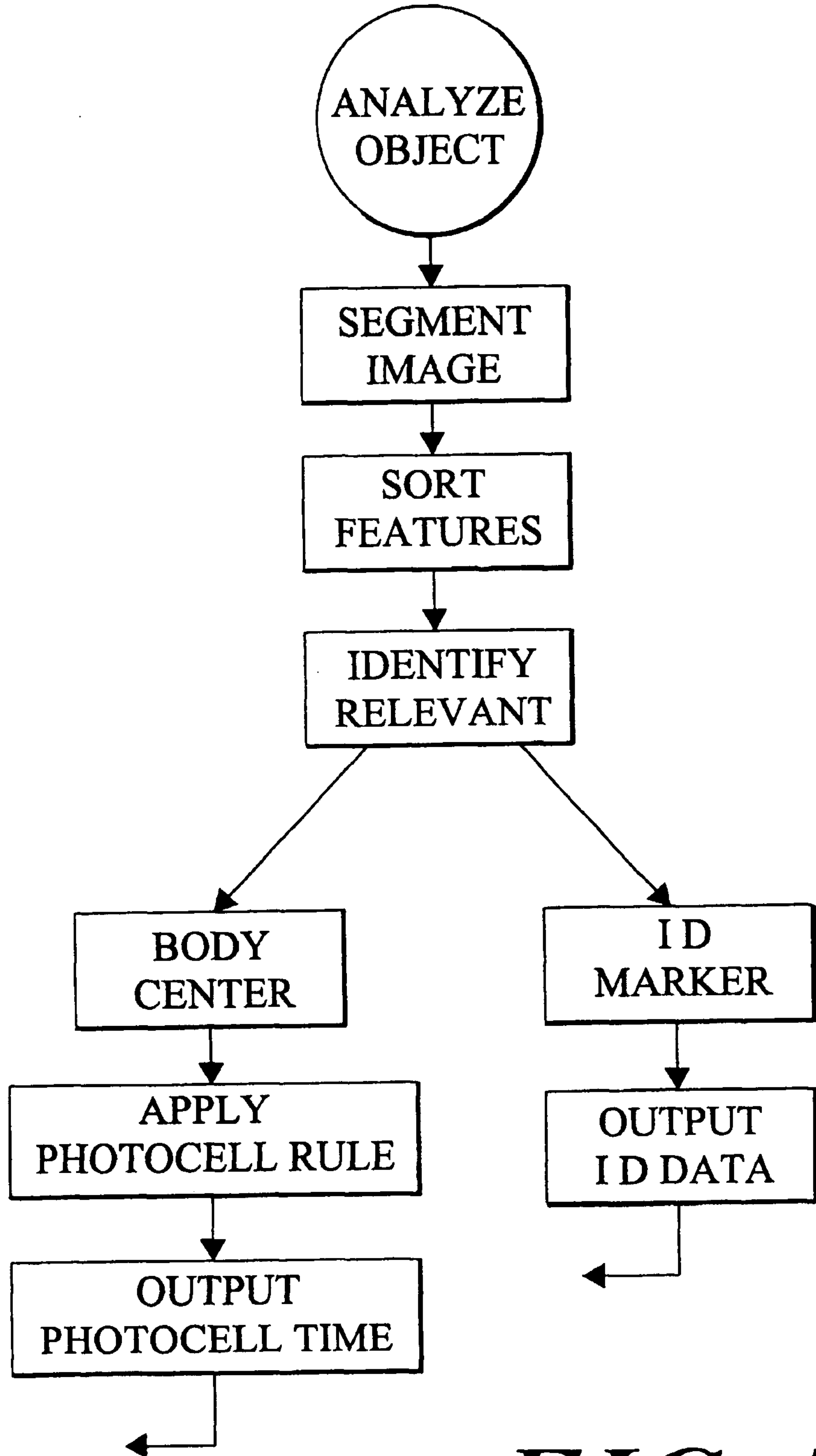

ANALYZE OBJECT
SEGMENT IMAGE
SORT FEATURES
IDENTIFY RELEVANT
BODY CENTER
APPLY PHOTOCELL RULE
OUTPUT PHOTOCELL TIME
I D MARKER
OUTPUT I D DATA

FIG. 5

CAMERA WITH OBJECT RECOGNITION/ DATA OUTPUT

TECHNICAL FIELD

The present invention relates generally to systems which monitor and record motion events, and it relates to cameras and systems for time-sequential imaging and display, with application in numerous fields. Most particularly, the invention provides a station imaging camera and system useful for measuring timed sporting events and imaging movement along defined tracks at stations. The invention also relates to systems and methods for generating a scene by compiling successively-scanned line objects, as described for example in applicant's commonly-owned U.S. Pat. Nos. 5,552,824 and 5,657,077.

Prior art systems employing standard photographic techniques to monitor the finish line of a race are known. In such a system, typically one or more cameras equipped for high resolution imaging view the finish line and capture sequential pictures at a high rate for later inspection by a judge or other interpreter. However, this process is cumbersome, wasteful, and time-consuming, in that it requires, for example, an apparatus of photographic film and paper, processing chemicals, and image enlargers or projection optics to be employed with their respective methods of operation, development and finishing. Consequently, most races rely on human judges and revert to "photo-finish" technology only in extremely close or important events. The Specialty Instrument Corporation provides a number of electronic and photo-finish systems of this type marketed under the trademark Accutrack. U.S. Pat. No. 3,829,869 exemplifies one such Accutrack system.

Because of the problems with the "photo-finish" technology, numerous other systems for monitoring racing events have been developed. However, these other methods and systems for timing sporting events present new difficulties. Video systems which record and display races in a standard television or video format are popular, but regardless of the particular implementation of these systems, a portion of the electronic image remains on an analog medium, such as recording tape. Since analog data from the systems consists of a continuum of information over time, it is relatively difficult to accurately apportion to a unique time interval. It is even more difficult to access a particular moment in time in the recorded sequence because the associated system must search the storage medium, typically having a long physical length in a spooled format, e.g., a video cassette. This presents both limitations and difficulties for users wishing to simultaneously record, view the current race, and review earlier segments of the race (or even a previous race) because only one user can have access to any of the information stored and recorded at any one time.

A further difficulty in analog data is that it must be converted to a signal usable for video, television, or a computer before it is displayed. For example, after a completed search, a selected video tape segment is typically sent to active memory before it can be processed by a computer and, quite possibly, by supplemental complex graphics generators. Altogether, the analog format and related processing adds to the time required to review a race and therefore lengthens the decision making process.

Another problem faced by race systems occurs in the management of extended time events, like a marathon or bicycle race, which can last for hours or until each entrant finishes. The runners or cyclists cross the finish line in groups; and for long periods, the finish line is void of persons. The relevant information at the finish line is thus sporadic, and includes significant amounts of "dead" time. In analog systems, this dead time is nevertheless recorded and stored so that the image record will retain time synchronism with the event, even though the intervening dead time images are generally useless for other reasons and add to the time required for processing and reviewing the race.

Several race systems have attempted to improve the management and accessibility of data taken during a race by transforming the recorded information to a digital equivalent. But, these systems also often revert to an analog format before displaying the race on a screen. As examples, U.S. Pat. No. 4,797,751 shows a video recording system having both digital and analog sections to provide display on a common cathode ray tube (CRT). U.S. Pat. No. 5,136,283 similarly describes another partially digital system which displays races on a standard television format. These analog/digital systems still have many of the problems inherent in entirely analog systems.

Linear sensor arrays or line cameras as described more fully in the above-mentioned commonly owned '824 and '077 patents, have now also been applied to such imaging tasks. These cameras have been used for assembly line imaging as well as for athletic competition finish line imaging. They offer the advantage of extremely accurate time resolution of a restricted area, namely of a linear strip imaged by the camera, and by taking a time series of frames directed at a fixed station, a two-dimensional linear/temporal or t,y-dimension image may be formed that bears a readily interpretable similarity to the customary optical spatial or x,y-dimension image of the scene. As set forth in applicant's above mentioned patents, the data stream from such cameras can be used to detect and deal with moving objects to provide high temporal and spatial resolution in real time. This entails transmission of a generally continuous stream of line image data to a processing system, which then attends to the annotation, indexing, compression and storage of the relevant views so that a small sub-portion of relevant views can be placed in digital random access storage and readily recalled, typically within minutes or seconds of the original image acquisition, for detailed inspection. However, effective use of such line-imaging camera systems has required extensive software-mediated data handling by a trained technician operating the system, and great demands are imposed on the data transmission and synchronization for effecting image assembly, time synchronization, and image frame recording and access.

It is, accordingly, an object of the invention to provide an improved camera and system for recording and displaying a time-sequential scene of bodies crossing a plane along a track.

These and other objects will become apparent in the description below.

SUMMARY OF THE INVENTION

The invention features, in one aspect, a camera for forming a time sequential scene of bodies moving across a plane in space, wherein the camera recognizes the appearance of an object within its limited field to trigger or flag its image output stream. The system includes at least one camera which is aimed to image objects crossing a line of interest, wherein the camera time-sequentially captures the object by imaging it onto an array of detector elements and converts the sampled signal into a digital line image, or frame, which passes to a frame buffer. Each digital image

passive component

frame uniquely represents a fixed slice of the moving scene at a moment in time. A processor is situated within the camera, and communicates with the buffer, processing information from corresponding pixels or larger blocks of time offset frames to detect an object which has entered the line field of view and responsive thereto, controls the image data output stream or produces data coordinated with the image stream. For example, in one aspect, the camera detects arrival or departure of objects in the image field and thereupon operates to produce or enable an image data output stream, or to annotate the stream and enhance its information content by indicating such detection. In a basic aspect, the camera may detect entry or departure of a probable object at the image field, and tag or enable the relevant portion of the image stream. In a further aspect, the camera operates on the detected image data to make object-based determinations. In this aspect of the invention, the processor inspects image features, such as shape or orientation of the presenting features, or duration of the features, and confirms the presence of an object. It may then make a further determination, such as the identity of the object, or the probable crossing time of the object, to provide an output data stream which annotates information or results, greatly facilitating the processing of event data and the real time announcement of results.

X

In a basic embodiment, the processor detects the start of one or more objects crossing a finish line, and enables the image data output stream from the camera only during the interval when activity appears in that region. Static or background image frames may be flagged for separate or non-critical handling, may be sent to a separate port which interfaces with a data local storage unit, or may be simply suppressed and later be reconstructed from earlier or later frames. Thus, in one embodiment, frames of a displayed scene which add no information are removed, either temporarily or permanently, effectively withholding from the stream those frames in which there are no activity or bodies crossing the plane—while retaining a time reference for the remaining frames, which collectively display all the visible changes of a continuous scene. Alternatively, rather than suppressing the static portions of the image stream or acting as an on/off control of the output stream, the processor may simply flag the active (or the static) frames of the stream so that an external processor receiving the camera output is able to operate more effectively to code, index and store the relevant image frames in suitable memory locations for access, inspection, or other processing or reconstruction as appropriate.

In a further embodiment, the processor processes frame data when frame changes have indicated the presence of a contestant at the imaged field, to perform a photocell determination. This processing sorts or compares blocks of frame data corresponding to features, such as the head or body of a horse, or the arms, legs and torso of a runner, to confirm the presence and position of a finish line crossing. The processor then determines, typically by interpolation or back-interpolation, the line-crossing time, which may for example be associated with the nose of the horse, or torso of the runner. These determinations are typically made by software feature checking routines which scale the body size of the object to the expected velocity of the event and the frame rate of the camera to estimate the exact finish line time. By detecting body features in the correct order before triggering the finish line time determination, or by otherwise confirming the presence of an object, the camera avoids falsely triggering, for example on a shadow of a back-lit runner that may precede the actual crossing.

In yet another or further embodiment, the processor processes frame data to detect patterns or markings on the imaged objects, such as numbers identifying the contestants, and the output frames in which these objects or indicia were detected are flagged or indexed with the detected identifiers. The line camera may be set up at a plane of interest, such as the finish line of a race or an intermediate position along the track. In this case, the frame times may also be processed with the flagged identifiers at the observed plane, either the finish line or an intermediate position, to quickly show rankings or relative positions, speed or other ratings for immediate display in an automated manner without waiting for a judge's inspection of the digitally reconstructed images as required in previous image timing systems. The camera output augmented with this data thus directly interfaces with a computerized race management system so that desired frames are quickly accessed by their index information for review. A user at the computer console can command a variety of functions provided by the invention to manipulate and analyze the captured scene, most particularly to display any portion of the scene of bodies moving across the plane and access an associated time and/or identities of contestants for each frame within the sequence of line crossing images.

assoc. pic w/ participant

The system of the invention is particularly useful in recording and managing the official times of objects or entrants crossing a finish line in a digital race management system since it both preserves all imaging information and simplifies the storage, transmission and selective retrieval of finish line information. A user can therefore record and display the bodies crossing the plane of interest, i.e., the finish line, with accuracy while enhancing the ability to immediately employ information embedded in the images in real time, both to review and edit the stored images for finish determinations, and to effect fast automated display of unreviewed results. The invention thus provides an object-controlled compression and information enhancement of the camera output data.

The system constructed in accordance with the invention also provides, in another aspect, an in-camera memory subsystem communicating with an in-camera processor, wherein blocks of frame data are processed to detect an object, to detect a background, and to control start time and/or end time for active imaging segments which are to be transmitted out of the camera for analysis. According to this aspect of the invention, the processor may analyze imaged frames and set a retroactive start time for frame transmission, or a prospective end time to assure integrity of the preserved image record. A timer in the camera maintains a common time line, and the frames in transmitted segments are time labeled. In addition to finish line and mid-course tracking and identification, the camera and system are also useful for various photocell determinations.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will be understood from the following description taken together with illustrative figures showing details of construction and certain preferred embodiments, wherein:

FIG. 1 illustrates a system employing a camera in accordance with the invention for recording and displaying a time-sequential scene of bodies crossing a plane;

FIG. 1A illustrates further details of the camera and system of FIG. 1;

FIG. 2 shows a representative image constructed according to the invention from discretely sampled line objects;

FIG. 3 illustrates a typical display of a racing scene generated by a system in accordance with the invention;

FIG. 4 illustrates operation of an in-camera detector for image output control in accordance with the invention;

FIG. 4A illustrates internal object detection processing for output control; and

FIG. 5 illustrates further object information processing.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a camera **12** in accordance with the invention mounted in a system for imaging and recording a sequence of bodies crossing a plane in space, which illustratively is shown containing the finish line FL of a track. As discussed further below in connection with certain embodiments, a camera **12***a* may also be positioned to image an intermediate line L in a race monitoring system. In other aspects the system may be positioned to image a station in a robotic process line; however, for clarity of exposition below, the example of an event recording camera **12** is discussed in detail.

As ~~shown in FIG. 1, the~~ camera **12** is mounted on a stand S which places the camera above and to the side of the finish line, with the camera itself oriented and aligned such that the finish line is imaged onto a linear sensing array, the output of which is electrically scanned or sampled at a high rate to produce a time-resolved image data stream. Preferably the camera is positioned in the vertical plane of the line FL, and aligned so that the plane is projected onto the sensing array. For example the camera may be above and to the side of the track, or in certain cases may be mounted overhead. The camera is connected in a race management system **10** which includes the digital camera **12** and an image management computer **16** connected to various display or recording devices and interfaces.

As shown more fully in FIG. 1A, the camera **12** of the present invention possesses an objective lens or optical assembly **15** which images a line portion **18** of the object field of its objective lens **15** onto an array of detector elements **20**, preferably a Line Scan Charge Coupled Device (LS-CCD) having a pixel length of one thousand to several thousand pixels. An imaging controller **22** samples the detected light level at the detector elements **20** at successive times and amplifies the output signal with a gain controlled detector amplifier **24** and digitizes the processed signal with an A/D converter **26**, to acquire successive frames of image data. The signal frames, each representing a line of pixels, are taken at a rate above several hundred lines per second, preferably about 400–1000 lines per second, and are stored in a buffer **25**. Buffer **25** may, for example, be implemented with about one megabyte of VRAM, corresponding to somewhat under one minute of raw image frame data at that sampling frame rate. Each sampled image represents a frame of digital information at a unique moment in time, and may illustratively have the format of an ordered data string with a pixel value for each of a thousand successive pixels forming the line array. As set forth in greater detail below, the frames from the sensor and residing in the buffer are further processed in the camera to form the camera output stream.

The CCD **20** may be a monochrome (grey scale) or a color (e.g., RGB) CCD, but for clarity below shall be generally described as though it were a monochrome sensor, with only brief mention of several adaptations to color sensors where this is relevant for preferred implementations of object detection. In general, the color implementations utilize ordered triplets of light amplitudes rather than a scalar value, and may employ different data compression schemes tailored to the unique format of the data structures involved. Reference is made to the aforesaid commonly-owned patents for several useful details of implementation such as color palletization, data stream compression in the camera, and image management in the system **10** as a whole.

As further shown in the race management system of FIG. 1, a second camera **12***a* is positioned elsewhere on the track to image a line L, which may, for example, be positioned a few tens of meters after the starting line to detect the starting order of runners, or may, for example, be positioned at the quarter mile mark for a horse race to detect the order of horses and/or their times at that intermediate station of interest. Camera **12***a* is also connected to or in communication with the system **10**, so that its image data is processed and stored, or is reviewed by an official, or is passed to a timing or display system. Preferably, the camera **12***a* communicates by wireless transmission, so that lengthy cabling, line matching and signal synchronization protocols and the like are not required for its set up. With this configurations, the camera **12***a* will in general provide its data during a time interval which is earlier from or distinct from that of camera **12**, so it is generally not necessary to provide a second channel or an elaborate addressing or multiplexing protocol in the management computer to handle the output of camera **12***a*, because the data handling elements of the system **10** which process incoming images receive image data from only one of the cameras at a given time.

As discussed more fully below, cameras **12**, **12***a* preferably each "crop" their image output stream. By "crop", applicant means that the cameras either send information only for the times of image activity, or else annotate the data stream with flags to indicate the portions of the stream which are active. In the latter case, the annotations are received with the image data stream and the processor of system **10** may operate with a higher degree of automation not requiring operator oversight or control.

In accordance with a principal aspect of the present invention, the imaging controller **22** in the camera performs these additional functions by operating on the frames acquired in the buffer **25** to detect object information in the image, and, responsive thereto, annotate or control the image data output on the output signal line **28** for connection to an external image management system **16**. It will be understood that line **28** is shown for purposes of illustration as a line, but is more generally to be understood to be a communication link, such as a local radio frequency link so that the camera may alternatively send its data output by RF transmission.

Several representative object detection operations will now be illustratively presented. It will be familiar to those in the art that two-dimensional (line×time) image frames created by an event recording line camera appear smeared in the width direction, with the x- or width dimension proportional to the dwell time of the object at the imaged object line L or FL, and inversely proportional to the speed of the object crossing that line. Conversely, background field, when not obscured by a contestant passing in front of it, remains always the same, forming horizontal bands of fixed color or intensity passing through each pixel position of the line sensor **20**. These are the image frames in buffer **25** upon which the object detector described below operates. Preferably each line image frame is marked with a time reference, so that this time information appears within the digital information of the frame. In a preferred embodiment, the time reference for each frame is indicative of the time the camera **12** captured the picture. This may be an absolute time, or a time relative to the start of an external event or

trigger signal, and it may be derived from other signals, such as the signal from a start detection sensor **84** (FIG. **1**), or an external time source, or an internal camera timer, preferably with a system time synchronization protocol as described in applicant's aforesaid patents.

In general, the external computer storage and image analysis system **16** may include elements such as software for adding text or linking images with identifying data to index the raw image data, and for indexing, accessing, and quickly displaying and analyzing the times appearing in the image data. Systems of this type are extensively described in the aforesaid two commonly owned U.S. Patents.

By way of context, the main control computer **16** of the external management system may have a central processor **40** that processes the blocks of information stored within an internal memory **36** and organizes the line frames into two-dimensional image frames for displaying the scene and time contents of a sequence of digital line frames on a display monitor **42**. The central processor **40** preferably also controls the automatic operation and memory management of the system **10**, and responds to inputs at the keyboard **44** and mouse **45** so that a user can selectively command the display of any scene captured by the system **10**, including a real-time display or previously recorded segments. It is more particularly contemplated that a user can access the unique times associated with any portion of the scene for immediate announcement of finish times and view the frames for visual resolution of close finishes. Computer outputs may also be configured to drive external displays such as signboards, for announcing results, and remote monitors for simultaneous viewing by judges. A number of desirable features of such external race management systems have now appeared in several commercial products, and no further description of their operation need be given here.

Further, by way of example useful in understanding the time and position determinations made and recorded in applicants line camera systems, FIG. **2** illustrates an object **60** which is in motion along a horizontal axis, and wherein a camera (not shown) is focused on the object **60** with a field of view (FOV) substantially in the vertical plane across that axis. As each frame is captured, a portion of the object **60**, i.e., a line object, is uniquely and spatially represented as a digital line image frame. In FIG. **2**, the successive line objects captured by the system are illustratively shown on the object **60** as successive rectangular stripes **62**. For each of the line-images **62**, the digital camera **12** correspondingly generates a frame by sampling the image of the line object according to the number of detector elements within the array **20**. That is, each of the line objects **62** is digitally segmented along its length by projection via the camera objective onto the line sensor **20**, forming a digital image frame having the number of pixels present and sampled in the detector array **20**. In a real-time aspect, line frame **64** represents the most recently captured frame, and the remainder of the object **60** to the left of line frame **64** has yet to be captured by the system, while those lines **62** to the right of line **64** have already been captured as the object **60** moved through the object plane. A series of successive line frames are then assembled next to each other to form a picture.

A scene or composite image of an object assembled in this way when displayed on the computer **16** appears very much like an actual spatial image of an object passing by the FOV of the camera **12**, especially when the object moves at a relatively constant speed and when the frame rate is selected in a proportion to the expected speed of the object such that the width dimension is not appreciably expanded or reduced from the normal spatial representation of the imaged object. Notably, in such images, any stationary background **70** in the field of view which lies along the finish line, such as a wall, is imaged identically in successive line images, so that when a frame is assembled from successive lines, the background appears as horizontal stripes each having the fixed color or intensity of the imaged stationary feature.

FIG. **3** illustrates a typical image frame formed in this fashion of a group of runners crossing a finish line. Among the artifacts due to the mode of generation of this image, it is apparent that the background appears as a set of horizontal stripes when not occluded by a runner, and each runner appears frozen in the exact posture he assumed as successive strips of his body crossed the finish line. Nonetheless, except for a slight dimensional stretching or compression effect along the lateral direction, each runner appears approximately as in a normal spatial image taken from the perspective of the fixed camera position. Thus his suit color, entry number, facial traits and other identifying features are, or would be, captured in the image.

Returning now to a description of camera operation, each digital line frame captured by the system **10** of FIG. **1A** is stored in the buffer **25**, and the control microprocessor **22** operates on this line image data to control the camera output. The invention contemplates several different forms of object recognition and output control, examples of which will now be described. First among these is the recognition of an object moving across the line FL.

FIG. **4** is a flow chart illustrating this operation in a basic prototype embodiment of the invention. In this embodiment, the microprocessor **22** in the camera processes raw image frames from the buffer **25** to detect the presence of an object moving across the line field of view, and it controls the output data stream so that the image frames are sent out by the camera only when there is finish line activity, while precision time marking is maintained. In terms of hardware, the microprocessor loads the line frames into VRAM of moderate size, e.g., a 2 MB VRAM, and then processes successive lines to detect finish line activity. In a further aspect, when a pattern of probable motion is detected, the processor confirms the pattern, and retroactively tags the start of the active image sequence for transmission out of the camera, while inactive frames or "dead time" images are simply compressed, deleted, or even sent to tape backup without occupying system bandwidth.

In addition to the buffer storage or VRAM, the camera's internal microprocessor **22** preferably has a RAM capacity of about 32 MB or more, allowing the camera itself to store up to several minutes of time-resolved active finish line images. This is far longer than the typical duration of line-crossing images in a track or equestrian event, so that in the event of a faulty external transmission link or equipment failure, the relevant scenes remain available for analysis in the camera memory.

As shown in FIG. **4**, the object detection proceeds by detecting the beginning of an object entering the image field. This is done by a sorting/comparing procedure on the incoming line image frames to determine a likely entry of an object into the field, and confirm it. First, the processor loads a set, illustratively eight, of image lines to form a sample strip eight by one thousand pixels in size, and partitions the strip into 8×8 blocks. Each strip thus comprises a vertical column of 125 8×8 light-sampling blocks. The microprocessor then loads and similarly partitions the next eight image lines so that it has two 125 block sets of light values, and then proceeds to compare the pixel values of each block with those of the immediately preceding corresponding

block of pixel values, to develop a measure of the amount of localized change in the successive image light values. The comparison may, for example, take the difference in the sum of pixel values of each block. If the difference, representing the total change in intensity of the successively detected light values, is less than a threshold T_1, e.g., 10% of the total pixel summed amplitude, in all blocks, then the processor simply fetches the next eight lines, partitions it into blocks, and again performs a similar comparison, proceeding in this fashion until a light value change above the threshold level is detected.

It will be readily understood that the stationary background, imaged at constant intensity and position, will in general fluctuate by the noise level of the pixel sensors. In addition, when the scene is an indoor scene illuminated by artificial light, extreme periodic fluctuations in light intensity at the line frequency will occur. Thus, the use of multiple successive lines and multi-pixel averaging blocks to detect change serves to decrease the effect of noise and periodic light variation on the detection of a meaningful change in light level. Thus, a 50–60 Hz line signal, with 100–120 zero-crossings per second will require a block of about 80–100 msec duration to assure that aliasing of the sample period and the illumination flicker does not result in false readings. The detection threshold T_1 is set to be greater than the expected normal or noise fluctuation of the 8×8 blocks. A value of ten per cent of the total amplitude is a useful threshold value for determining a significant movement into the field of view.

As further shown in FIG. 4, when a block intensity difference greater than the T_1 threshold is detected, the processor sets the BEGIN-OBJECT flag at the time t_0 of the first line of the current block. In alternative embodiments, the processor may wait for two, or more generally n blocks in a row to differ, so that it confirms the sustained presence of an object before it annotates the image data or sets an output control signal. In that case the camera starts counting, and when the block value remains different and above the threshold for at least, e.g., five consecutive blocks in time, the change is recognized as being due to an object moving across the field of view. The processor retroactively sets the BEGIN-OBJECT flag at the start of the active sequence. The flag data may be sent as a separate data indication along with the continuous image data stream to facilitate external processing and indexing of the line image data, or the flag data may be used to directly initiate the output of image data from the camera commencing at time t_0, so that image data is sent to the output port only when an object has been detected. In another embodiment, the camera may be set to catch the image data starting at a preset time before the first detected change frames, for example at 0.1 seconds before the first detected change, so that the finish line sequence will include images as the contestant nears the finish and shows the first parts of a contestant crossing. Thus, the nose of a horse, or hand of a runner, will appear before the torso breaks the ribbon. Such details, while coming earlier than the event which is traditionally recognized as crossing the line, are useful for resolving ambiguities when multiple contestants cross nearly simultaneously. For example, a projecting hand may be followed to identify the position of a contestant even when the torsos of several contestants are simultaneously occluded or overlapping in the field of view. Thus, the active image sequence may be set to include a fixed leader portion.

As further shown in FIG. 4, once the runners have been detected in the image the processor then switches to a different analysis procedure which monitors or analyzes the object now appearing in the image frames to derive additional information. In a basic embodiment, the processor continues processing sample image strips in a manner somewhat analogous to the initial object-trigger analysis, to determine when the object has passed or the finish line activity ceases. A suitable set of determinations is shown in FIG. 4A for this aspect of the processing. When the end of the object is detected, the processor then sets an END OF OBJECT flag, preferably causing the output controller to turn off the output stream or enter a dormant mode. For this latter detection, the processor detects whether all pairs of blocks differ by less than a threshold T_2. Advantageously, the processor may employ a different threshold, $T_2<T_1$ or may require that a sub-threshold level of homogeneity persist for a greater number of sample strips, or both, before concluding that the moving objects have passed. This operation avoids falsely signaling the end of a sequence when in fact a relatively homogeneous object, such as the body of a horse, rather than the stationary object has remained in the field of view front of the camera. For this determination in a color camera embodiment, the detection module may be advantageously set to use color change rather than, or in addition to, intensity as a detection measure. When the end of activity is detected, the END OBJECT flag is at the first line of the group of frames that attained the static signal level, or may be set a fraction of a second thereafter, to signal the output control to cease transmitting line image output, or to label the frames when the cropping operation is restricted to annotation of the frames rather than physical switching of the camera output stream.

Thus the object recognition output controller first identifies a potential moving object, confirms the presence of motion, and then retroactively identifies the active image frames. Similarly, to end the sequence, it identifies a potential stationary scene, confirms it, and sets the end cropping time to extend at least to the last active frame. In this manner only the image segments necessary for detecting, recording and judging movement across the finish line are annotated or sent from the camera, and these are automatically selected by the camera internal controller based on object detection. Automated object recognition in this manner eliminates the need for a human monitor to view and select image data at an external console, and reduces the need for massive external rolling image buffers and quick-access memory storage units since the relatively small subset of active image frames are pre-identified by the camera.

As previously noted, when no object is crossing the finish line, the background scene is static. As described more fully in applicants' aforesaid patents, by using a line-to-line compression algorithm, the amount of data to code a static sequence is greatly reduced or essentially eliminated, and by performing compression in the camera, external data buses need not handle the massive data flow of the raw line images. The system of the present invention however offers an additional operating improvement, in that the camera internal processor effectively sends only short intervals of highly-relevant image data, and, as viewed by the system **16**, it effectively appears to turn itself ON and OFF exactly when needed. Indeed, when operated with in-camera random access memory of only 32 MB, the camera may also effectively store the entire relevant set of data for a single race, since this typically amounts to only a half minute or less of actual finish line crossing scenes. Since each line frame includes the time it was imaged, the beginning and end times are all that is needed to reconstruct the static dead time scenes from the last frame.

In addition to flagging the active segment of the image data generated by the camera's line sensor, the invention

contemplates further internal processing of identified object to produce object-based data. This is shown schematically in FIG. 5. Two distinct types of data will be briefly illustrated. One is object identification, which proceeds by way of image analysis subroutines to detect color, number, bar code or other individual features of the contestants as they pass. This is discussed in greater detail below. The second, which will now be discussed, may be called "photocell determinations". In accordance with this latter aspect of the invention, the in-camera processor performs a more detailed image analysis of the object-containing frames to fit the contestant to a template, recognizing defining parts of the body, and then applies a species/event specific interpolation or estimation rule to determine the probable crossing time.

As applied, for example to a horse, the processor may process direct-overhead image lines to detect the body of a horse crossing the line, then, while correcting for frame rate and event speed (which affects the horizontal distance scale), identify the crossing time by the frame which occurred a fixed time or distance before the mid-point of the body. This estimation procedure will produce an estimated time, based on a standard species size and shape, which can be used for initial announcement scoreboard displays. For example, the processor may set the "nose" of a horse to be 1.6 meters ahead of its center, or the nose of a greyhound to be 0.7 meters ahead of its center. By adding the identified time to the image output data stream, an immediate index is provided to the race management system, and full-frame images may be immediately constructed and reviewed to determine the exact crossing time. Inspection of FIG. 3 shows a typical crossing configuration for a human track event. As applied to a person, the relevant image analysis may be triggered by the initial appearance of a hand, arm or leg in the field. In that case, the image analysis may proceed by a fixed rule, such as setting the probable crossing to be about 30–50 centimeters after the initial limb, or it may proceed with further image analysis to detect the central mass of the body, e.g., the torso or stomach, and to set the estimated crossing time at the appearance of this feature. A race official would then view the image frames so identified to determine the exact crossing time by observing, for example, whether the torso were angled forward, and seeing which line of the composite frame actually contained the leading edge of the torso. Other photocell crossing determinations may be readily implemented by employing rules specific to the speed of the event and the species of contestants.

Returning now to a description of the object recognition and feature recognition aspects of the camera, we note that the above description of object detection has spoken of pixel values as though they are a scalar quantity. However when a three color line camera is employed, the determination of movement may proceed differently to achieve faster processing, more accurate object detection or even detection of particular features or identifiers. In one such variation for simple object detection, the three different color values of the blocks in successive sample strips are compared separately, and their differences summed separately to provide a more refined test of scene changes. For example, the sudden appearance of red pixels when red had been entirely absent would immediately indicate a new object arrival. This color comparison detection allows a smaller size block to be used for the object recognition determination. Alternatively, the contestants may be actively assigned markers or jerseys of distinctive colors to identify each one by a color or set of colors conspicuously carried or appearing in their attire. The processor in that case is preferably programmed to store the colors associated with each contestant in the image (e.g. royal blue=Joe Smith=contestant 17) and to provide that data in the output stream.

Alternatively the external race management system may compare the detected color identifiers to a previously established table of runners' identities. In this case the color-annotated image stream received from the camera has its color and time components passed to a simple subroutine which checks the color against an identification table and signals the runner's name on a display. Such an identification table may be set up during an initialization procedure, preferably implemented in the external race management system, during which, for example, a separate hand-held camera is pointed at each contestant and the contestant's identity is entered as a processor analyses and logs the distinctive color and sets up the identification table. In this case, the object-controlled line camera of the present invention may perform additional processing to provide the necessary identification data, for example as an alphanumeric record in the preamble of each line image frame occurring in its output data stream.

Applicant further contemplates that when the controller 22 is operated to identify the particular objects in its view, the processor will perform other or additional image analysis beyond the detection of threshold light changes or color determinations. Such additional processing may for example include edge recognition and object segmentation to separate the overlapping images of runners and determine what individual colors are carried when a relatively small image region contains several colors at once. The invention also contemplates systems wherein a special identification marker is worn by each contestant so as to be visible in the image. Thus, for example, when used for an equestrian event, the markers may be attached to the top of each horse's back, and the camera may image the finish line (or an intermediate station along the track) from directly overhead so that all markers are oriented directly toward the camera and no marker is ever blocked by the adjacent runners. Such markers may include, for example, oriented bar codes, or lines or blocks of different colors forming a distinctive combination. The color markings may also be advantageously shaped to assure quick and dependable detection. This may be done, for example by arranging the different colors in color bands which are oriented in a manner to assure that they are imaged on separate detection pixels of the camera or have a substantial dwell time on the detecting pixels. For example, the bands may be worn parallel to the direction of motion, giving them an extended dwell time in the image, and be offset across the direction of travel so that they are imaged onto different pixels of the sensor. They may also, where size permits, be offset along the direction of travel, leading to temporal resolution of the color combination in the image. This makes them readily detected when the line images are sampled in blocks of narrow height along the image sensor or are imaged for only a short time duration.

passive unp. id

In yet other embodiments, the processor may incorporate an optical character recognition module to simply read the number on a contestant's jersey, or may process the image lines using patterns of a bar code reader to recognize bar code identifiers. In general, however, the use of a mark configured for line-camera detection, and preferably color identification markers is preferred to the use of character or bar code technology, in order to reduce the possibility of occlusion and misreading of the sought-for markers.

character recognition to read #'s

When used as an event recording system, such as at the finish line of a race, the object triggered line scan camera system of the present invention may be operated to record and resolve positions one thousandth of a second apart, or less, while greatly reducing the real time bandwidth demands imposed on external system elements, and without introducing any noticeable delay in the transmission of necessary image data. The data annotation of output frames, even without physical cropping of static or dead time images, also results in a system wherein the data handling

and RAM storage demands placed on the external race management system are reduced.

The invention being thus disclosed and representative embodiments and features thereof described, further variations modifications and equivalents will occur to those skilled in the art, and all such variations, modifications and equivalents are considered to be within the scope of the invention, as defined by the claims appended hereto.

What is claimed is:

1. An event recording camera system for forming a time sequence of images, comprising

a camera which generates a first sequence of digital line image frames of a fixed position in space, each frame of said first sequence representing a line image view that is captured by said camera at a moment in time and imaged onto an array of detector elements, said first sequence including active segments imaged at times wherein moving objects cross said fixed position, and inactive segments wherein no moving objects cross said fixed position

a buffer in said camera for storing said first sequence of frames as they are generated, and

a processor in said camera operative on said first sequence to detect an object and produce an object detection signal so as to selectively present said active segments at a camera output.

2. A system according to claim 1, wherein said processor communicates with the buffer to receive data from frames of said first sequence and compare data from successive frames to detect an object, such that said processor retroactively identifies start of an active imaging segment.

3. A system according to claim 1, wherein frames of the active imaging segment include frame time information.

4. A system according to claim 1, wherein said processor communicates with the buffer to receive data from frames of said first sequence and compare data from successive frames to detect end of an object, and sets the end of an active imaging segment.

5. A system according to claim 1, wherein the active imaging segment includes object identification information.

6. An event recording digital camera including an optical imaging element for forming a light image of a restricted visual field, and an image sensing element for generating a digital image frame from the light image, timing means in said camera for generate time signals and a processor in said camera operative on a sequence of said digital image frames for detecting movement of an object in said restricted visual field, and providing an information output in response to said detection,

wherein said image sensing element is a line sensor and said processor processes data from plural frames to detect identifier information carried by said object in said restricted visual field, and wherein said processor further provides an active segment with the object identifier information whereby image data transmitted out of the camera is suitable for automated display of identity data.

7. A digital camera according to claim 6, wherein the processor includes a memory, and said processor identifies active imaging segments in said memory in the camera.

8. A digital camera according to claim 6, wherein the processor crops said sequence by identifying start of an active segment and transmitting image frame data with time markings commencing at the start of the active segment.

9. A digital camera according to claim 8, wherein said line sensor generates frames at a rate substantially over one hundred frames per second.

10. A digital camera according to claim 9, wherein the processor detects bar code, number or color coded identifiers carried by the object.

11. A digital camera according to claim 6, wherein the processor detects object features to produce a photocell determination.

12. A digital camera including an optical imaging element for forming a visual image of a field, an image sensing element for generating a multi-pixel electrical output from the visual image, and circuit means in said camera for processing said multi-pixel electrical output to provide an image data stream including digital value image pixels, wherein said circuit means includes a processor operative on said image pixels to identify information bearing portions of said data stream and control camera output to transmit said information,

wherein said image sensing element is a line sensor and said processor processes data from plural frames to detect identifier information carried by an object in said visual field, and wherein said processor further provides an active segment with the object identifier information whereby image data transmitted out of the camera is suitable for automated display of identity data.

13. A digital camera according to claim 12, wherein the processor ~~annotates the image data stream with data codes indicative of at least one of start of object, end of object,~~ and ~~identity of object.~~

~~14. A digital~~ camera according to claim 12, wherein the processor controls output of the camera to selectively pass image frames containing moving object images.

15. An event recording video camera comprising

means for imaging a visual field

a line sensor for converting a line portion of the imaged visual field into electrical signals representative of pixels of the image of said field

circuit means for processing said electrical signals to form a digital output stream containing digitized pixel values of a sequence of frames at a high scanning rate

a buffer for storing said digital output stream before transmission, and

a processor operative on contents of the buffer for comparing sets of data from the buffer and identifying image data associated with moving objects, said processor controlling said output stream responsive to the identified data.

16. A video camera according to claim 15, wherein said processor compares block sum light values to detect beginning or end of object motion in the visual field.

17. A video camera according to claim 15, wherein said processor image-processes blocks of frames to detect an object identifier and controls said camera to transmit image data annotated with an indication of object identifier.

18. A video camera according to claim 15, wherein said processor image-processes blocks of frames to detect an object feature and controls said camera to transmit image data and estimated crossing time data.

19. A video camera according to claim 15, wherein said pixel values include color values and said processor processes values for each color separately.

20. A video camera according to claim 15, wherein the processor compares blocks of image frames over time to detect a change indicative of image frame activity and said processor applies a different threshold to detect end of image frame activity than to detect start of image frame activity.

* * * * *

United States Patent [19]

Hermanns et al.

[11] **4,274,076**

[45] **Jun. 16, 1981**

[54] **DEVICE FOR DETERMINING THE MOMENT WHEN COMPETITORS IN A RACE ARE PASSING THE FINISH LINE**

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[21] Appl. No.: **133,839**

[22] Filed: **Mar. 25, 1980**

[30] **Foreign Application Priority Data**

Apr. 7, 1979 [DE] Fed. Rep. of Germany 2914114

[51] **Int. Cl.³** **G08C 21/00**

[52] **U.S. Cl.** .... **340/38 L**; 340/23; 340/32; 340/323 R

[58] **Field of Search** .... 340/31 R, 32, 23, 38 L, 340/323 R, 309.4, 39; 235/92 T, 92 TA, 92 TC, 92 GA; 368/113; 272/4, 5; 273/86 R; 455/99; 343/7 VM

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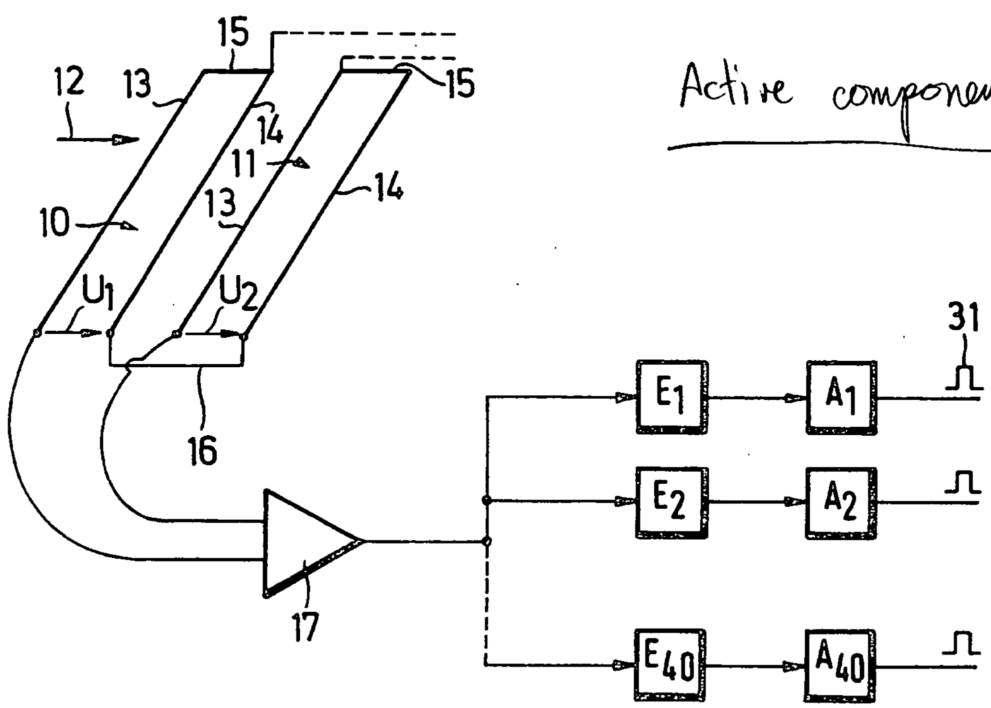
Primary Examiner—James J. Groody

Attorney, Agent, or Firm—Spensley, Horn, Jubas & Lubitz

[57] **ABSTRACT**

In this system for determining the moment when competitors in a race pass the finish line, each competitor is fitted with a transmitter. Arranged at the finish line are at least two receiving antennas, the signals from which are combined in opposite sense so as to form a difference signal. A system output signal then is produced which has a leading edge that occurs when the difference signal crosses zero. This output signal indicates that a competitor has passed the finish line.

8 Claims, 4 Drawing Figures



Active components

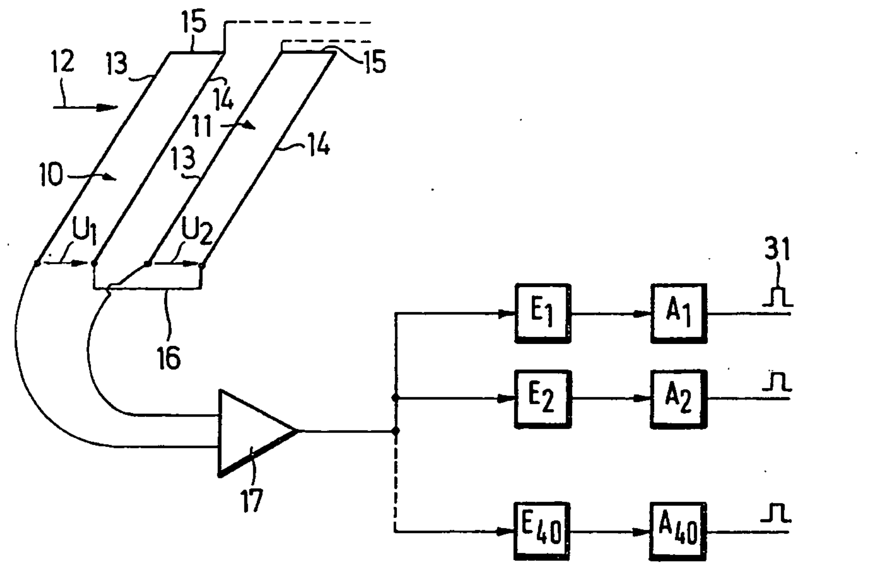

15
12
13
15
14
11
14
10
13
U1
U2
31
16
E1
A1
E2
A2
17
E40
A40

FIG. 1

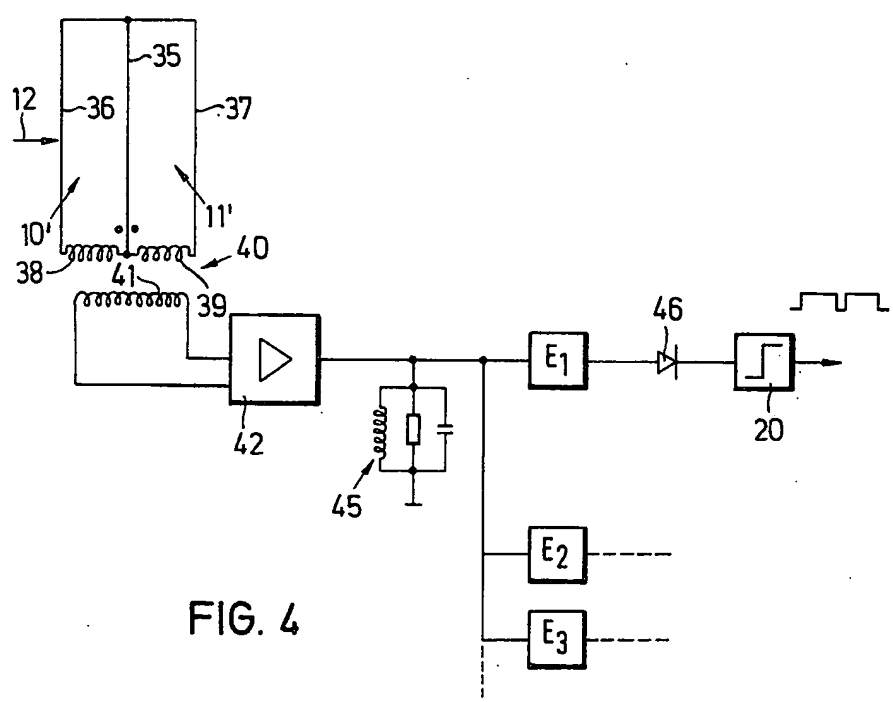
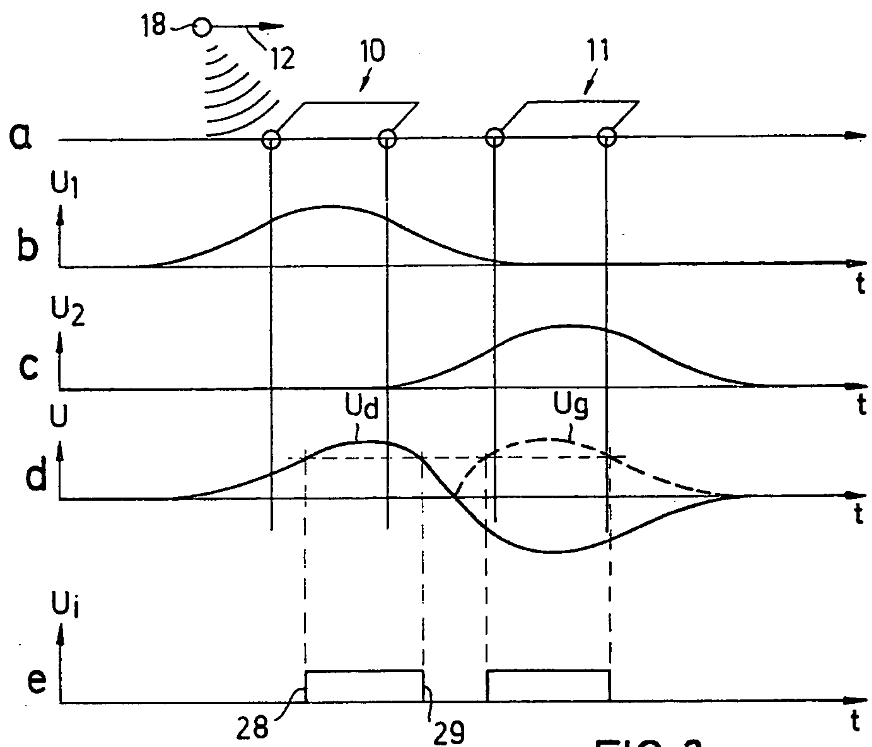

35
12
36
37
10'
11'
38
41
40
39
46
E1
42
20
45
E2
E3

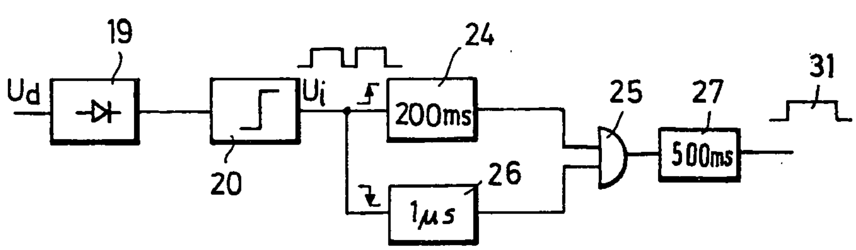
FIG. 4



18
12
10
11
a
U1
b
t
U2
c
t
U
Ud
Ug
d
t
Ui
e
28
29
t

FIG.3

FIG.2



19
Ud
Ui
24
200ms
25
27
500ms
31
20
26
1μs

DEVICE FOR DETERMINING THE MOMENT WHEN COMPETITORS IN A RACE ARE PASSING THE FINISH LINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a device for determining the moment when competitors in a race are passing the finishing line.

2. Description of the Prior Art

Due to the methods of electronic timing, a very accurate determination of competition times is possible. What is critical, however, in many cases, is the exact determination of the moment when the finishing line is passed. This is so, above all, when several competitors are participating at the same time in a race, for instn. in a car race. It may happen that several competitors are passing the finishing line within a short distance of each other in an overlapping manner so that it cannot be readily determined which moment of passing the finishing line should be attributed to which competitor. While, after all, the accurate moment can be determined by a photo-finish, the evaluation always takes some time. Alternatively, the use of a light barrier extending along the finishing line only gives an information about the passing of the first competitor in case of a nearly simultaneous passing of several competitors. If light barriers are mounted vertically to the racing course, a bridge at the end of the racing course must be erected. In car races, such a bridge is a danger for the competitors and it gives an obstruction of visibility for the spectators. Moreover, it is a disadvantage of light barriers that the light transmitters and light receives may become dirty and that manipulations and interferences can be expected from third parties.

It is the object of the invention to provide a device of the type mentioned at the outset hereof which permits an exact determination of the moment when competitors in a race are passing the finishing line even if the finishing line is passed nearly at the same time, interferences and manipulations by third parties being practically excluded.

SUMMARY OF THE INVENTION

To solve this problem, it is provided, according to the invention that the competitors are fitted with transmitters which transmit selective characteristics, that at the finish, at least two receiving antennae are arranged consecutively in the direction of the racing course and connected to receivers which are tuned selectively to the characteristics of the transmitters and that an evaluating device is connected downstream of each receiver and determines the transmission of the signals from the first to the second receiving antenna to supply a corresponding signal representing the moment when a competitor passes the finishing line.

assigned to individual

Each transmitter and receiver are assigned selectively to one particular competitor, so that it can be exactly determined when he passes the finishing line. When the finishing line is passed, the transmitter of the corresponding competitor first reaches the receiving area of the first receiving antenna and subsequently, it is covered by the receiving area of the second receiving antenna. The determination and evaluation of the transmission permits to exclude the effects of homogenous electromagnetic fields because such homogeneous fields simultaneously excite both receiving anteannae with the

same intensity so that no transmission can be recorded. Stationary interfering transmitters or transmitting devices in the vicinity of the racing course cannot produce signals as to the passing of the finishing line even if they are provided with the characteristics of the corresponding competitors. As a result, a high degree of absolute reliability is obtained. The characterization may be effected for inst. by a selectivity of frequency in that the transmitters of the competitors emit different frequencies while the receivers connected to the receiving antennae are selectively tuned to one of the transmitted frequencies. Other types of characterization are possible alternatively. For inst. all transmitters may operate on one frequency only which, however, is modulated with another frequency for each transmitter. Thus, only one sole receiver is required which delivers frequency signals to selective evaluating devices. Alternatively, different pulse clock rates of one sole transmitted frequency are also possible for each receiver.

It is preferred that the receiving antennae are induction loops which are embedded in the ground. They can be flatly embedded and do not form obstacles in the finishing area. In car races, the transmitters can be mounted at the bottom plates of the vehicles or in a hole of the bottom plates. To this effect, the transmitters are spaced only slightly from the roadway, while they are protected on top by the bottom plate or by the car body. Due to the small distance from the ground a reduced transmitting power will do. The ground acts as a swamp for the emitted radiation which cannot cause radio interferences accordingly. The distance between the two induction loops should be in the order of the distance between the ground and the transmitters. In view of the small road clearance of racing cars the receiving antennae or induction loops are closely side by side so that a very accurate determination concerning the passing of the finishing line is possible as required for the high speed of racing cars.

The receiving antennae are preferably coupled with each other in opposite direction for the difference formation of their signals. Upon approaching of a transmitter, a positive signal is for inst. generated in the first receiving antenna whose voltage amplitude will decrease again upon passing by the first receiving antenna to subsequently go through zero. When, thereafter, the receiver is passing the second antenna, it will create a negative voltage at the second antenna. The zero passage of the total signal of both receiving antennae can be determined very accurately by electronic means.

A device for the rectification of the difference signal of the two receiving antennae may be provided to determine the zero passage. The rectified difference signal is supplied via a pulse former stage to the differentiating device, which selects one of the two pulse edges generated near the zero passage of the difference signal to generate the resulting signal for the passing of the finishing line. One optionally may select the leading or the trailing pulse edge to determine the zero passage. Both pulse edges being very closely side by side, the decision concerning the pulse edge selected for the evaluation will not have any influence on the accuracy of the measuring result.

To avoid simulating of passing of a finishing line by interference pulses, the pulse former stage may be connected to a time member having a receiving time which is longer than the duration of the rectified difference signals and of the antennae. The output of the time

member is supplied to one input and the output of the differentiating device is supplied to the other input of an AND-circuit. This, it is ensured that the signal of the differentiating device is only evaluated if the time member has been put into operation by the excitation of the first receiving antenna.

The induction loops may be fitted closely side by side to comprise a common central wire, so that only three wires are necessary for realising two induction loops.

For the coupling in opposite direction, the induction loops can be connected to primary coils of a transformer which are wound in opposite winding directions.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the Figures, some embodiments of the invention will be explained hereinafter.

FIG. 1 is a schematic illustration of a first embodiment of a device provided at the finishing line of a car racing course,

FIG. 2 shows a block diagram of an evaluating device according to FIG. 1,

FIG. 3 shows different signal curves at the receiving antennae and in the evaluating device and

FIG. 4 is another embodiment of the coupling of the receiving antennae.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to FIG. 1, two induction loops **10** and **11** are embedded in the ground of a racing course at the finishing line. The driving direction of the cars is marked with arrow **12**. The induction coils comprise each two wires **13**, **14** extending in parallel across the racing course and being interconnected at one end by a connecting wire **15**. The wires **13** and **14** are in one (horizontal) plane. With respect to the wires **14**, the wires **13** of the induction coils **10** and **11** are provided ahead in driving direction. The free ends of the wires **14** are interconnected by a connecting wire **16** so that the induction coils **10** and **11** are connected in an opposite sense. The free ends of wires **13** are connected to the input terminals of an amplifier **17**. The output of the amplifier **17** is connected to a great number of selective receivers E_1 to E_{40}. Each of the receivers is tuned to the transmitter frequency of one of the frequency-selective transmitters (not illustrated) mounted at the racing cars. Said tuning is realised in the known manner with quartz-controlled oscillators. To avoid standing waves at the induction loops **10**,**11**, the wave length should be large as compared to the width of the racing course.

If a racing car provided with a transmitter **18** is passing the induction loops **10**, **11** in direction of arrow **12**, there is formed at the free ends of the induction loop **10** the time curve of a voltage U_1 as shown in FIG. 3*b*.

At the free ends of the induction loop **11**, there is formed the time curve of voltage U_2 as illustrated in FIG. 3*c*. The voltages U_1 and U_2 increase with an approach of the transmitter **18** and they reach their peak point when the transmitter **18** is in the center of the corresponding induction loop. Subsequently, they decrease again.

Since the induction loop **11** is poled inversely with respect to the induction loop **10**, the voltage curve U_d as shown in FIG. 3*d* is formed at the input of the amplifier **17**, which curve corresponds to the difference between voltages U_1 and U_2.

In the evaluating units $A_1 \ldots A_{40}$ connected at the outlet side of the receivers $E_1 \ldots E_{40}$ the voltage curves U_d of the individual receivers are processed. FIG. 2 shows a block diagram of one of the evaluating units.

The positive portion of signal U_d is supplied via a two-phase rectifier **19** to a pulse former stage **20**, acting as a threshold circuit, i.e. it generates an output signal "0," when the input signal is below a threshold value and an output signal "1" when its input signal is above a threshold value. The signal at the output of the two-phase rectifier is designated as U_g in FIG. 3*d*. Its amplitude values are only positive.

At the output of the pulse former stage **20**, there is formed the pulse signal U_i illustrated in FIG. 3*e*. It consists of two longer pulses which are separated by a pulse gap. In the center of the pulse gap, there is a zero passage of signal U_d.

The output signal of the pulse former stage **20** is supplied to two time members **24** and **26**, which may consist of monostable flip-flops. Time member **24** responds to the positive pulse edge of signal U_i and has a running time of 200 ms. The time member **26** responds to the negative pulse edges of signal U_i and has a running time of 1 μs. The outputs of the two time members **24** and **26** are combined in an AND circuit **25**, whose output signal is supplied to a third time member **27** having a running time of 500 ms. At the output of the time member **27**, there is formed the pulse **31** pertaining to the passing of the finishing line and its rising edge is marking the moment when the finishing line is passed. The time member **24** is made operative by the rising edge **28** of the voltage U_i. The AND-circuit **25** is enabled by the time member **26** which is put into action by the trailing edge of voltage U_i. This is the moment which is taken for the passing of the finishing line.

In FIG. 4, another embodiment is shown in which the two induction loops **10'** and **11'** are also provided transversely relative to the driving direction **12**, but they have one common central conductor **35**. The ends of the first induction loop **10'** consisting of the conductors **35** and **36** are connected to a first primary winding **38** of a transformer **40**. The conductors **35** and **37** of the second induction loop **11'** are connected to the second primary winding **39** of the transformer **40**. The beginnings of the two primary windings **38** and **39** are dotted in FIG. 4. As evident, the two primary windings **38** and **39** are wound in opposite directions. Thus, the difference formation of the signals of the two induction loops **10'** and **11'** is achieved so that the curve of the difference signal as illustrated in FIG. 3*d* is formed.

The secondary winding **41** is connected to the input of the amplifier **42**.

A band pass **45** connected to the output of the amplifier **42** allows only the frequencies of the interesting range of frequency of the receiver $E_1 \ldots E_{40}$ to pass.

The individual selective receivers $E_1 \ldots E_{40}$ are connected to the band pass. A diode **46** is connected at the outlet side of each receiver and the pulse former stage **20** is connected to said diode. The circuit behind the pulse former stage **20** corresponds to the circuitry shown in FIG. 2. The difference formation of the signals of the receiving antennae and the rectification by the transformer are shown in the embodiment of FIG. 4.

Circumstances arising, it might be suitable to provide a second group of receivers and to connect them e.g. to the transverse wires **15** according to FIG. 1. As a result, the protection against interferences by external transmitters is increased additionally. The distribution of the

electromagnetic field or its change in time due to the movement of the transmitter is measured by the difference formation of the two antennae. Stationary transmitters cannot influence the device accordingly and cannot cause it to respond.

We claim:

1. A system for determining the moment when competitors in a race pass the finish line, in which race the competitors are each fitted with a transmitter, said system comprising:

at least two receiving antennae arranged at the finish line, the signals from said antennae being combined and supplied to an evaluating equipment comprising:

means for coupling said signals from said antennae in opposite sense to form a difference signal therebetween,

a rectifier receiving said difference signal, and

an output signal circuit connected to said rectifier and responsive to a voltage change of the rectified difference signal for generating a system output signal indicating that a competitor has passed the finish line.

2. A system according to claim 1 wherein said output signal circuit comprises:

a pulse former stage connected to said rectifier circuit and producing an output when said rectifier difference signal exceeds a certain threshold, the output of said pulse former stage thereby comprising a pair of rectangular wave signals corresponding respectively to the signals from said antennae, and

a pulse producing element, connected to said pulse former stage, and responsive to one of the two pulse edges of said pair of rectangular wave signals which occur near the zero passage of said difference signal, the output of said pulse producing element being a signal which begins at the time of passing of said finish line.

3. A system according to claim 2 further comprising:

a timer also connected to the output of said pulse former stage and having an operative time beginning at the start of the first of said pair of rectangular wave signals and which is longer than the time duration of the rectified difference signal, and

signal combining means for providing said system output signal only upon the occurrence of an output of said pulse producing element during the operative time of said timer.

4. A system according to claim 1 wherein each of said receiving antennae comprises a separate induction loop embedded in the ground, said at least two loops having a common central wire.

5. A system according to claim 1 wherein said at least two receiving antennae are connected to oppositely wound primary coils of a transformer, the output of said transformer being coupled to said rectifier.

6. A system according to claim 1 wherein each competitor's transmitter has a uniquely different transmitted signal characteristic, there being a plurality of like evaluation equipments, together with

receiver means, connected to said antennae, for providing to each respective evaluation equipment the signals induced by a corresponding respective one of said transmitters.

7. A system for determining the moment when competitors in a race pass the finish line, each competitor being fitted with a transmitter, said system comprising:

at least two receiving antennas arranged at the finish line, each competitor's transmitter inducing signals in said antennas as the competitor passes the finish line,

difference signal formation means for combining the resultant signals from said antennas in opposite sense to form a difference signal therebetween, and

output signal means, connected to said signal formation means, for producing an output signal which begins when said difference signal crosses zero, said output signal indicating that said competitor has passed the finish line.

8. A system according to claim 7 wherein said output signal means comprises:

a rectifier circuit for rectifying said difference signal,

a threshold circuit providing an output when said rectified difference signal exceeds a certain threshold value, said threshold circuit output thereby comprising a pair of rectangular wave signals wherein the trailing edge of the first and the leading edge of the second of said pair occur respectively just before and just after the zero crossing of said difference signal, and

output pulse forming means, connected to said threshold circuit, for forming a single rectangular wave output signal which begins in unison with said trailing edge of the first or said leading edge of the second of said pair of rectangular wave signals.

* * * * *

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(12) United States Patent
Gluck

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(45) **Date of Patent: *Mar. 11, 2003**

(54) **IMAGING SYSTEM AND METHOD**

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(73) Assignee: **L. N. C. J. Limited**, Jersey (GB)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **08/955,484**

(22) Filed: **Oct. 22, 1997**

Related U.S. Application Data

(63) Continuation-in-part of application No. 08/607,582, filed on Feb. 27, 1996, now abandoned, which is a continuation-in-part of application No. 08/284,783, filed on Aug. 2, 1994, now abandoned.

(51) **Int. Cl.**[7] **G03B 17/00**
(52) **U.S. Cl.** **396/427**; 396/429; 348/157
(58) **Field of Search** 396/1, 2, 322, 396/419, 427, 429; 348/157

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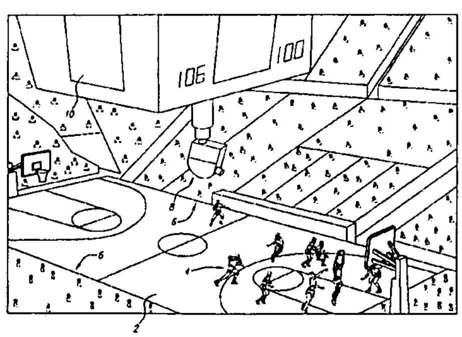
(74) *Attorney, Agent, or Firm*—Lyon & Lyon LLP

(57) **ABSTRACT**

There are described herein systems and methods for producing and distributing personalized photographic souvenirs for spectators of an event. Equipment well-known in the art is used to take photographs of performers at the event, and to scan images or take photos of items representative of the event, for example a ticket stub, advertisement, or team names and logos. In addition, at least one pan-and-tilt camera system, also well-known in the art, is used to take an orderly, indexed series of photos of the spectators such that substantially every spectator will appear in at least one spectator photo. The spectator photos are indexed according to a predetermined mapping algorithm which maps a particular location of the venue to a virtual sector. Individual souvenirs are then created at the venue in a centralized processing location, by organizing and combining a spectator photo with the other photos and/or scanned images. The souvenirs are then distributed to vendors who then present them to spectators in the sector or sectors from where the spectator photo was taken. The souvenirs may also be available to the spectator from the centralized processing location.

29 Claims, 4 Drawing Sheets



time element

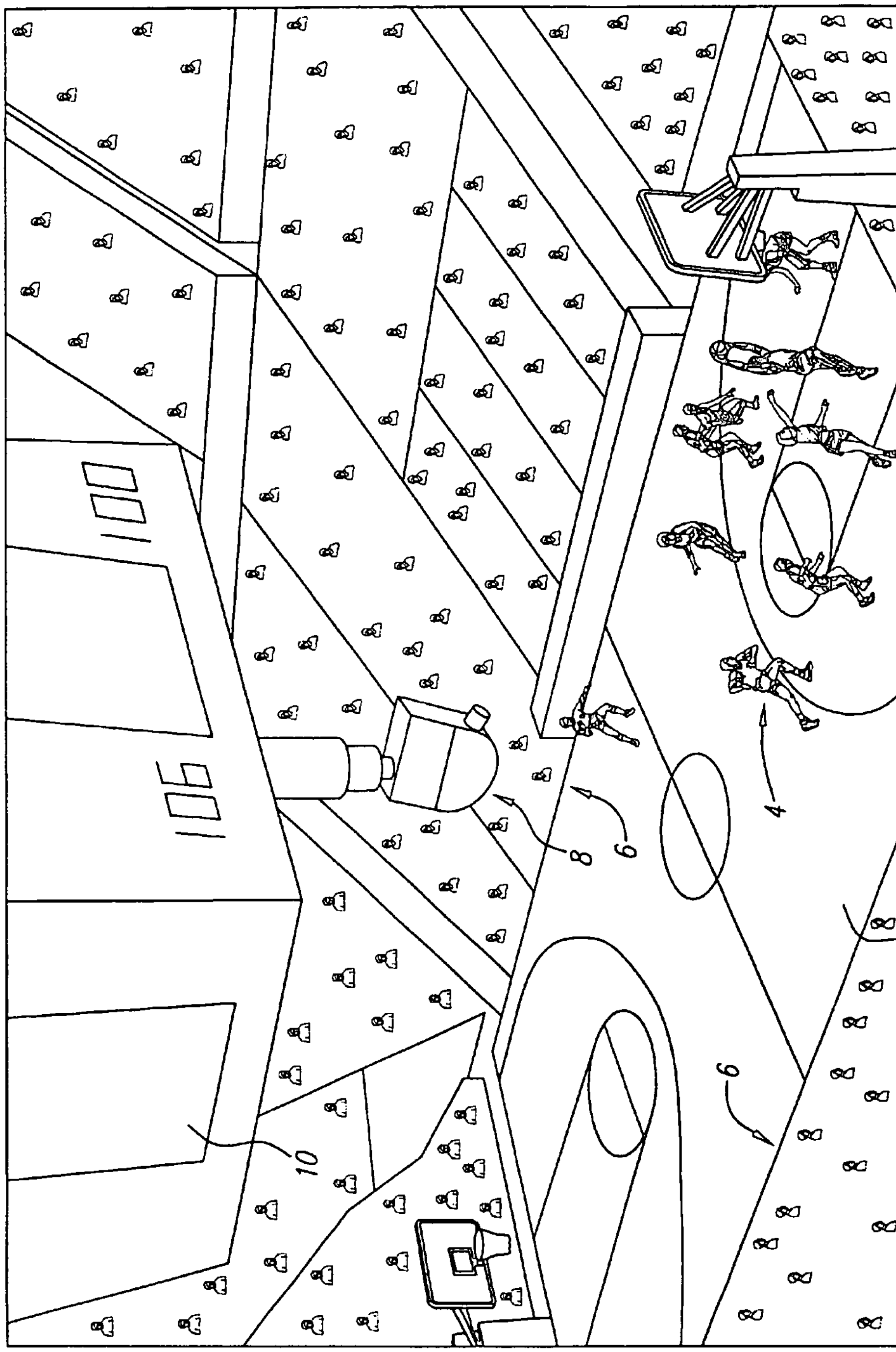


FIG. 1

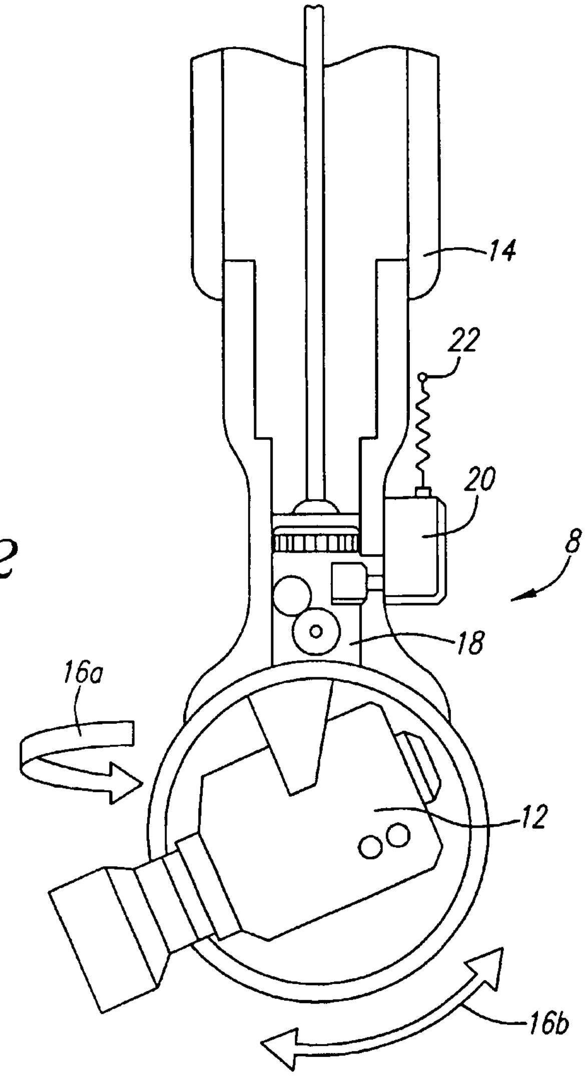


FIG. 2

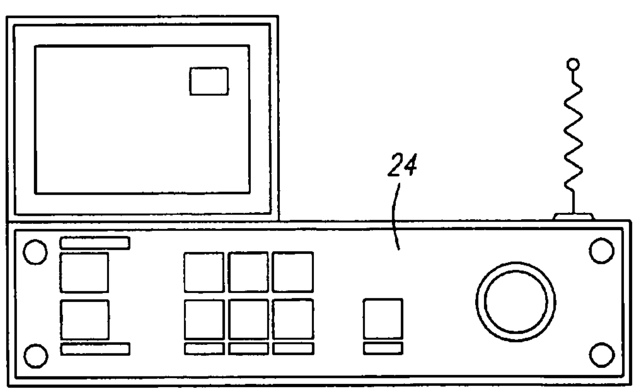


FIG. 3

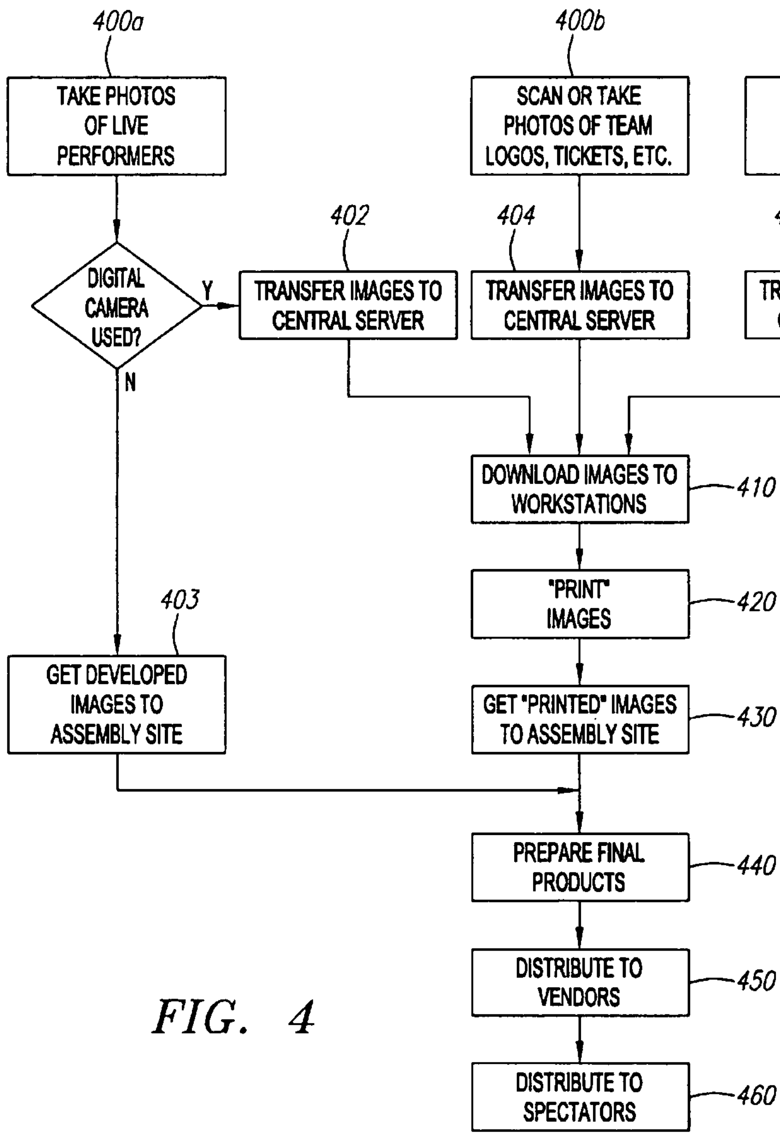

400a
TAKE PHOTOS OF LIVE PERFORMERS
400b
SCAN OR TAKE PHOTOS OF TEAM LOGOS, TICKETS, ETC.
400c
TAKE PHOTOS OF SPECTATORS
DIGITAL CAMERA USED?
Y
N
402
TRANSFER IMAGES TO CENTRAL SERVER
404
TRANSFER IMAGES TO CENTRAL SERVER
406
TRANSFER IMAGES TO CENTRAL SERVER
DOWNLOAD IMAGES TO WORKSTATIONS
410
"PRINT" IMAGES
420
403
GET DEVELOPED IMAGES TO ASSEMBLY SITE
GET "PRINTED" IMAGES TO ASSEMBLY SITE
430
PREPARE FINAL PRODUCTS
440
DISTRIBUTE TO VENDORS
450
DISTRIBUTE TO SPECTATORS
460

FIG. 4

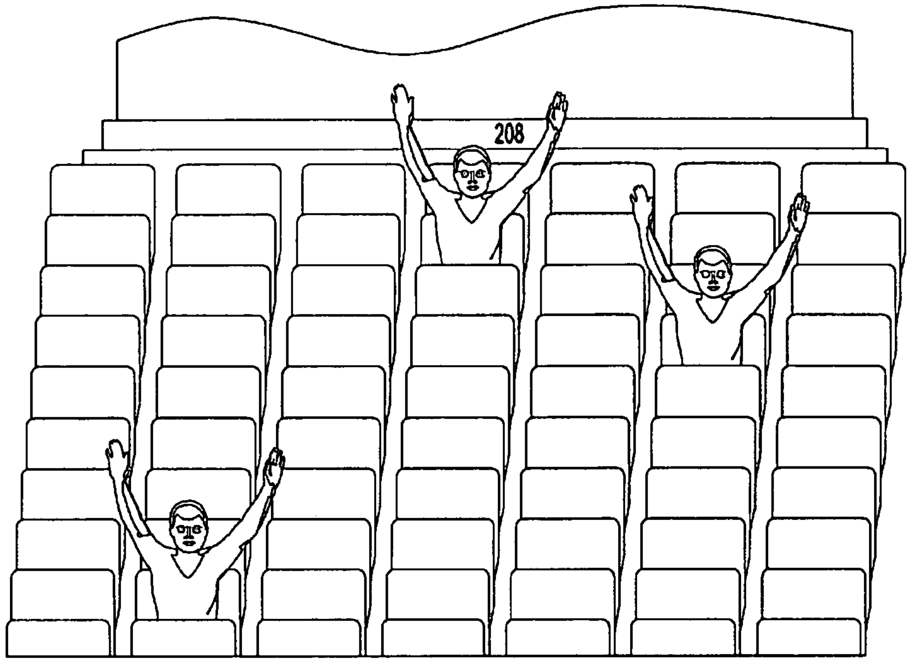


FIG. 5

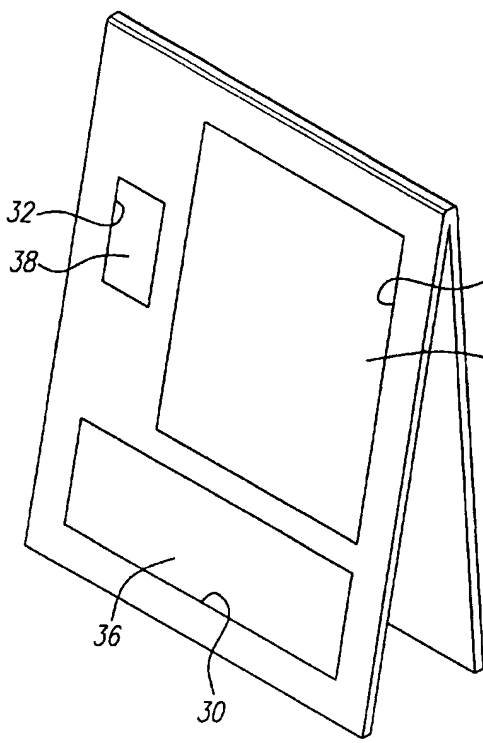


FIG. 6

IMAGING SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of U.S. application Ser. No. 08/607,582, filed on Feb. 27, 1996, which is a continuation-in-part of U.S. application Ser. No. 08/284,783, filed on Aug. 2, 1994, both abandoned. Priority to the above-mentioned prior applications is hereby expressly claimed, and the disclosures of the above-mentioned prior applications are each hereby incorporated by reference.

FIELD OF THE INVENTION

This invention relates in general to photography, and more particularly to systems and methods for producing and distributing personalized photographic souvenirs for spectators of an event.

BACKGROUND OF THE INVENTION

Observing live action events such as sports games, concerts, conventions, rallies, plays, and the like, is a major pastime. Many spectators attending these events consider them to be memorable and as such the spectators often take photographs of the events. Unfortunately, these photographs typically show only the action and not the spectator, or only the spectator and not the action. This results in obtaining a souvenir that for all practical purposes is no different than commercially available pictures and trading cards, or published photos of the event in magazines and newspapers. In addition, many spectators simply do not take photos at all, due to difficulty in carrying the necessary equipment, accessing a suitable photo-taking location at the venue, lack of suitable zoom lenses, prohibition by the venue owners, etc.

Since attending live events is usually a source of pride and joy which many people want to share with relatives and friends, it would be desirable for a spectator to have a personalized souvenir that indicates positively that the spectator did indeed attend the event.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved form of a personalized souvenir for a spectator at a live event.

Another object is to use photographs and/or scanned images of performers at the live event, photographs and/or scanned images of items representative of the event (e.g. a ticket stub, advertisement, or team names and logos), and photos of the spectators, to form the personalized souvenir.

Another object is to provide methods of obtaining the necessary photographs and/or scanned images and preparing the souvenirs such that the souvenirs can be distributed to spectators during or soon after the live event, at or near the site of the live event.

These and other objects are accomplished by the creation of personalized souvenirs which include real life photos, including photos of the spectators, to create an effect on the spectators known as "telepresence." That is, the spectators at a later time will typically be able to recall the event in a more realistic sense than if they looked at other souvenirs or photos which did not include photos of themselves combined with photos and memorabilia from the live event.

The systems and methods of the present invention use at least one pan-and-tilt camera system located at the event which takes an orderly, indexed series of photos of the spectators preferably soon after the start of the event, such that substantially every spectator will appear in at least one spectator photo. The spectator photos are indexed according to a predetermined mapping algorithm which maps a particular location of the event venue to a virtual sector (so called because the sector boundaries may not necessarily correspond to physical sections at the venue). Individual souvenirs are then created at a centralized souvenir assembly site, by organizing and combining a spectator photo with the other photos and/or scanned images. The souvenirs are then distributed to vendors who then present them to spectators in the sector or sectors from where the spectator photo was taken. The souvenirs may also be available to spectators from the centralized assembly site. Truly personalized souvenirs of attendance at the event are thus provided for large numbers of spectators, who may obtain the personalized souvenirs in a relatively quick and easy manner while still at the event venue.

Other objects of the present invention will be apparent from the detailed description which follows, when read in conjunction with the in drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a typical venue of a live event (a basketball game) illustrating a pan-and-tilt camera system attached to the scoreboard above the center of the court.

FIG. **2** shows a typical pan-and-tilt camera system used in conjunction with the present invention.

FIG. **3** shows a typical remote control unit for controlling the pan-and-tilt camera system.

FIG. **4** is a flow-chart showing how the photos and other images are routed to a central system server and then downloaded to workstations where they are manipulated and combined to form the finished products, which are then distributed.

FIG. **5** is a copy of an actual photograph taken during an experiment with the systems and methods of the present invention.

FIG. **6** shows a sample layout of a personalized photo souvenir of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. **1** shows a basketball court **2**, during a basketball game, with players **4** on the court **2**. Spectators **6** are seated in the stands in a usual manner throughout the venue. A pan-and tilt camera system **8**, well-known in the art, is attached to and positioned under the scoreboard **10**. Due to the design of typical gymnasiums, this location of the camera system **8** is preferred as it is in essentially the center of the court **2**, and therefore would typically be capable of taking photos of substantially all of the spectator seats without being obstructed. For other venues where such a placement is not available, the camera system **8** may be placed at other suitable locations, and/or there may be more than one camera system **8** to enable coverage of substantially all of the spectators. For example, at a football game, the camera system **8** or systems may be placed on the, goalposts, or attached to various strategic locations in the grandstands. At a baseball field the camera system **8** or systems may be attached to the foul poles, the fences, the home-run wall, etc. At a race track the camera system **8** or systems may be mounted to the guardrails, or stationed in the center of the track. These and other venues may require the camera system **8** or systems to be mobile. For example,

on golf courses the camera system **8** or systems could be mounted to mobile units, or hand-carried. Alternatively, the camera system **8** or systems may be located in a tethered balloon, low-flying low-speed aircraft, a blimp, a helicopter, radio-controlled hang-gliders, etc. In addition, the camera system **8** or systems may be mounted directly to structures as described, or they may be mounted tó telescopic brackets which in turn are mounted to the structures. The important feature of the location of the camera system **8** or systems is that they are capable of taking photographs of substantially all of the spectators at an event. In addition, the location of the cameras, the viewing angle, the lens aperture, the exposure time, the film speed and the type of lenses are selected carefully in accordance with usual good photographic techniques in order to account for variations in light among the spectators and the stage or playing field, the amount of motion and the speed of motion in the live action and among the spectators, the distance between the camera and the stage or the playing field, and the distance between the camera and the spectators.

FIG. **2** is an illustration of a typical pan-and-tilt camera system **8** used in conjunction with the present invention. The camera system **8** includes a camera **12** mounted to a camera support **14** which in turn may be mounted to a physical structure such as a goalpost or grandstand as previously described. The camera **12** has the ability to pan and tilt, as indicated by arrows **16***a* and **16***b* respectively, thus allowing the camera **12** to capture images of surroundings at 360° horizontally and up to 90° vertically. The camera system **8** also includes a motion control motor **18** and an R.F. control box **20** with an antenna **22**, so that the system **8** may be controlled by an R.F. remote control unit **24** as shown in FIG. 3. The camera system **8** and the control unit **24** shown in FIG. 2 and FIG. 3 respectively illustrate typical hardware well-known in the art, for example the camera system **8** may include a Sony DKC ST5 with flash trigger and/or spot-lighting capability, mounted on a cable-driven NS microwave model CD-20 mast with quickset QPT-90 pan and tilt, but it is understood that other camera systems and control units well-known in the art may be used without departing from the concepts of the present invention. Computer software drives the camera system **8** as will be discussed shortly.

The camera system **8** or systems may be operated manually or by remote control which is operated either manually or is driven by computer software. This includes panning, tilting, raising, lowering, zooming, and actual photo taking. If artificial light is needed, such lighting may be provided by strobe lighting systems pre-installed at the venue, flash units, high intensity spot light projectors, or any other suitable means. Such lighting devices may be hand-held and manually operated, or operated by remote control, or even computer driven. They can be mounted permanently, carried by operators, mounted onto the same brackets as the camera **12** or cameras, or mounted onto separate brackets. It is desirable that whatever the arrangement, the lighting over an entire sector being photographed should be as even as possible.

The equipment previously described, in conjunction with other hardware and software to be described herein, is used in accordance with the present invention to produce personalized souvenirs for spectators at live events. Turning to FIG. **4**, it can be seen that photo and image data from multiple sources (at steps **400***a*, **400***b*, and **400***c*) are sent to a central computer server, then distributed to various workstations where the data is manipulated, printed, and combined to form the finished products—personalized souvenirs. The central server is any computer well-known in the art capable of processing large amounts of data, for example a Macintosh Apple Power PC with at least 120 to 180 megabytes of RAM, running TEPS-1000 software.

The various photos and images at steps **400***a*, **400***b*, and **400***c* are gathered independently of each other, and may therefore be gathered at the same time. At step **400***a*, one or more photographers takes photographs of the performers (athletes, singers, actors, etc.) in a usual manner during the course of the event, preferably near the start of the event to allow enough time for processing the photos and creating and distributing the souvenirs. A digital camera, such as a Fuji DS-300 well-known in the art, is preferred, so that the images captured can be transmitted at step **402** to the central server after a photograph or group of photographs is taken. The images may be transported to the central server by a disc or cartridge, or transmitted via cable, wire, radio, infrared, or satellite, or any other means. If the camera or cameras used to take the photographs at step **400***a* are traditional analog type cameras, then instead of transferring the captured images to a computer server, the captured images are transported at step **403** in the form of undeveloped film to a film processing laboratory where they may then be scanned into the central server, or delivered as developed images to the souvenir assembly site.

At step **400***b*, photos are taken of admission tickets, event ads, team logos, names, predetermined slogans (e.g., "I was there!"), and/or other predetermined items indicative of the event, or said items may be scanned into a computer memory or permanent storage device. Other possible items or slogans include: a border of some appealing design to match the theme of the event; the time and/or the date of the event; the location where the event took place; an enlarged photo-within-the-photo so that a selected spectator or group of spectators can be seen more clearly; an arrow or a similar indicator connecting the actual spectator location in the photograph to the photo-within-the photo; a "halo" or similar indicator around the actual spectator location in the photograph to enable the viewer to locate the spectator more quickly; or even the name of the spectator. This will increase the informational content and hence increase the telepresence effect of the entire moment at a later date.

If cameras are used to capture these images, a digital camera such as the Fuji DS-300 may be used. If the images are scanned, scanners well-known in the art, for example a high resolution Hewlett Packard HP 4 Scanjet 4P, may be used. These images are then transported at step **404** to the central server by a disc or cartridge, or transmitted via cable, wire, radio, infrared, or satellite, or any other means, similar to step **402**.

Still referring to FIG. **4**, and turning now to step **400***c*, clear, in-focus photographs are taken of substantially all of the area of the venue designed for spectators. Using the equipment described in conjunction with FIGS. **1–3**, the camera system **8** or systems are controlled by computer software in which the venue has been mapped into predetermined sectors. The sectors may be based on physical boundaries within the venue, the characteristics of the camera system **8** or systems, such as shutter speeds, focal lengths, etc., or any other factors, but the ultimate goal is to define an area as a sector so that a single photograph may be taken of the sector which includes clear, in-focus views of substantially all spectators in that sector.

The determination of how big an area constitutes a single sector will usually require on site calibration and testing of the equipment prior to the event. At a particular venue, however, once the system is calibrated and the sectors are

mapped out, the settings will usually be accurate for future events. Once the venue has been mapped into these virtual sectors, such a mapping is programmed into software that is used to control the camera system **8** or systems. For venues that provide seating, a sector will typically contain from fifty to one thousand seats. For example, FIG. **5** is a copy of an actual photograph taken at a major sports venue during experimentation with the system and methods of the present invention. At this venue, it was determined that a sector corresponded to an actual physical section of the venue, section **208**.

Referring back to FIG. **4**, it is desirable for the camera system **8** or systems to take photos of substantially all of the spectators in a reasonable time, to still allow the personalized souvenirs to be produced and distributed at the venue by vendors. Thus, certain parameters are preprogrammed into the system **8** or systems. For example, the time for the system **8** or systems to begin taking photos, the first sector to take a photo of, the sequence of additional sectors to take photos of, etc. The degree of tilting, panning, raising, lowering, focusing, etc., for each photo is preferably also preprogrammed. Of course, any preprogrammed parameters may be changed or adjusted as needed, but preferably, an operator will simply initiate the photo-taking sequence either manually or by a remote command, and then the camera system **8** or systems will execute a series of preprogrammed steps to take clear, in-focus pictures of each sector in relatively rapid, continuous succession. The sequence at a particular venue should remain the same, once the camera system **8** or systems is calibrated for that venue.

Since the sector boundaries are actually virtual boundaries as described above, it is possible, and in fact likely, that some spectator groups could be split across sectors. Thus, in addition to taking photos of each sector, it is desirable to have photos taken that cut across sector boundaries, to increase the likelihood of a group of spectators being in a single photo. Thus, once the virtual sectors have been defined for a particular venue, the camera system **8** or systems are programmed to be stepped in increments such that the series of photos will cover individual sectors, as well as combined sectors cutting across sector boundaries. The horizontal sector overlap will typically be from 10% to 70%, and the vertical overlap will typically be from 1% to 25%, depending on the venue. If the camera system **8** or systems are manually operated, then the operator will adjust accordingly to achieve substantially the same results as described with the computer-driven camera system **8** or systems. The photos taken at step **400***c*, as just described, are then transferred at step **406** to the central server as described above for steps **402** and **404**. In each of these steps, **402**, **404**, and **406**, transfer of the images may require the use of a booster to ensure the data is not lost or corrupted during the transfer. This is especially true of step **406** due to the large volume of data.

Once the data from steps **402**, **404**, and **406** are loaded into the central server, the data is then downloaded at step **410** to individual workstations. Preferably, there is one workstation for approximately every five-thousand spectators. Thus, at a venue capable of supporting twentythousand spectators, there would be four workstations. The workstations are well-known in the art, and may be for example a Macintosh Apple Power PC similar to the central server. The images may be manipulated at the workstations using common software, for example Adobe Photoshop, to properly size, orient, and otherwise edit the images to prepare them for the assembly into the final souvenir.

Attached to each workstation is a series of printers, preferably from one to eight printers per workstation, and more preferably from three to eight, and more preferably from five to eight. The printers are color computer printers or dye-sublimation printers or other similar photographic-quality printers well-known in the art, for example Sony UP-D8800 printers. After any editing is performed to the images as described above, the images are printed at step **420** directly to paper using the printers just described.

Still referring to FIG. **4**, once the images are printed, they are all collected and brought together at step **430** to the souvenir assembly site. The central server and other hardware may or may not be at the souvenir assembly site, although it is preferred that at least the workstations and printers are at the site, along with any film processing equipment needed for processing analog type film. Thus, the images are preferably printed directly at the assembly site. In addition, the assembly site is preferably at or near the venue. Once the images are all at the assembly site, workers, and or computers prepare the final personalized souvenirs at step **440** by selecting the desired images and arranging them onto a single frame or support in a predetermined pattern. The images may be separate images combined onto a single matte or frame, or they may be edited and merged by software into a single photo-realistic sheet. The images are preferably spaced apart in a predetermined manner so as to fit in a frame or matte with pre-cut windows.

A typical final souvenir may be arranged as shown in FIG. **6**. The frame may be an easel frame as shown in FIG. **6**, or a single-piece frame. The windows may be cut out and sized for various images, and to correspond to the image-editing software templates such that the edited images will be properly sized and shaped to fit into the windows. For example, FIG. **6** shows cutout windows **30**, **32**, and **34** for an event ticket **36**, spectator photo **38**, and an action photo **40** respectively. The size, type, and arrangement of the various images may be altered without departing from the present invention. For example, additional images such as team logos may be placed on the souvenirs. Also, the images may be of a type described in co-pending U.S. application Ser. No. 08/607,582, filed on Feb. 27, 1996, in which the images are a composite photograph image comprising the live action and background spectators with an enlarged view of the selected spectator superimposed with the composite image. By combining the images as described above, a sense of telepresence is thus created, because images of the individual spectators are in a collage-like presentation with images of the live action and other items indicative of the event.

The final souvenirs are sorted, either manually or by computer. For example, software may control which images are sent to which workstation, based on the origin of the images. Thus, it will be known which sectors are handled by each workstation. In this way, the vendors for specified sectors will know which workstations to collect their souvenirs from at step **450**, and may then venture out to their assigned sectors and distribute the souvenirs to the spectators at step **460**. The spectators will then have a chance to view the souvenir, and will likely be able to find themselves in the spectator photo.

During the event, especially at a sporting event with large picture screens, the spectator images may be displayed along with advertisements and/or instructions on how to obtain the souvenirs. In addition, or alternatively, there may be video units located throughout the venue with software that allows the spectators to search for available spectator photos using simple commands. Even if a spectator fails to obtain a personalized souvenir from the vendor, there may be a walk-up window available at the assembly site (which is

preferably at the event venue) for spectators to obtain them. Thus, when a spectator approaches the walk-up window, they may either go through various spectator images available for review, or may simply provide their seating location to the operator. Once the operator has a seating location, the operator can search manually for the proper spectator photo, or the operator may enter the location data into a computer which is programmed to find the proper spectator photo based on the seat number, etc. For example, a database will have each seat number mapped to a specific sector. Then based on the starting photo sector, the number of frames-per-second taken by the camera system **8** or systems, and the particular system **8** used (if more than one was used) to take photos of that sector, the operator or software can determine which frame from which system **8** contains the desired spectator photo. The operator may then locate an existing souvenir with the desired photo, or if none exists then the operator may simply prepare a new souvenir with the desired photo by printing another copy of the desired photo.

If desired, through a separate indexing system similar to that just described, an individual image of a spectator may be manually or automatically extracted and then used to create an inset cameo showing substantially only the spectator. Space for the cameo may exist on a separate frame from that used for the standard personalized souvenirs, or the cameo may be placed instead of any of the other images in the frame designed for the standard personalized souvenirs.

While specific hardware has been described herein, it is understood that other hardware well-known in the art may be used without departing from the inventive concepts described herein. Similarly, though the present invention has been described as taking photos of spectators by taking their photos during the event, the present invention will also apply to taking photos of spectators while in line at the event, and the souvenirs can then be indexed by time, location, or even by a number known to the photographer and to the spectators when taking the picture so that the photographer could convey the information to the spectators. The souvenirs could then be made available at a later time. Thus, while preferred embodiments are illustrated in the drawings and have just been described herein, it will be apparent to those skilled in the art that many modifications can be made to the preferred embodiments without departing from the inventive concepts described. Accordingly, the invention is not to be restricted except by the claims which follow.

available @ a later time

What is claimed is:

1. A method of producing personalized souvenirs for spectators of a venue for a live action event comprising the steps of

capturing images of various views of the event including views of substantially the entire venue and spectators therein by remotely controlling one or more pan, tilt, and zoom cameras by using a remote control unit for control thereof,

transferring and storing into a central server the captured images,

indexing the captured images according to specific locations within the venue, and

making captured images available to spectators of the event via spectators identifying locations within the venue for which they desire to obtain pictures.

2. A method as in claim 1 wherein the captured images are indexed according to locations comprising virtual sectors of the venue.

3. A method as in claim 1 wherein images using substantially all possible views of a live venue are captured.

4. A method as in claim 1 wherein the images are captured by one or more digital cameras.

5. A method as in claim 1 wherein the images are captured by one or more film cameras, and the captured film images are scanned and transferred to the central server.

6. A method as in claim 1 wherein spectators can select an image they desire among the captured images at a location within the venue.

7. A method as in claim 1 wherein spectators can search for desired images through use of video display units.

8. A method as in claim 1 wherein captured images include images of portions of the live event and images of spectators and are combined to present composite images of the event and spectators.

9. A method as in claim 1 wherein captured images are printed via color printers and made available to spectators.

10. A method as in claim 1 wherein an operator initiates an image taking sequence to execute a series of steps to take a continuous succession of images throughout at least a portion of the venue.

11. A method as in claim 1 wherein a spectator can select a desired image by seat location.

12. A method as in claim 1 wherein captured images are transferred to the central server by any one or more of disks, cartridge, transmitted via cable, wire, radio, infrared and satellite.

13. A method as in claim 1 wherein captured images can be manipulated at workstations using image editing software.

workstations could be remote

14. A method as in claim 1 wherein the spectators are of a sports venue.

15. A method as in claim 1 wherein the spectators are of an entertainment venue.

16. A system for enabling personalized souvenirs for spectators of a venue for a live action event to be produced comprising

one or more pan, tilt, and remove control zoom cameras for capturing of images of various views of the event including views of substantially-the entire venue and spectators,

a central server to which the captured images can be transferred, and by which the captured images can be indexed according to specific locations within the venue, and

at least one viewing unit by which captured images can be made available to spectators of the event by spectators identifying locations within the venue for which they desire to obtain pictures.

17. A system as in claim 16 wherein the captured images are indexed according to locations comprising virtual sectors of the venue.

18. A system as in claim 16 wherein images using substantially all possible views of a live venue are captured.

19. A system as in claim 16 wherein the images are captured by one or more film cameras, and including a scanner for scanning captured film images and enabling them to be transferred to the central server.

20. A system as in claim 16 wherein spectators can select an image they desire among the captured images at a location within the venue at the viewing unit.

21. A system as in claim 16 wherein the viewing unit comprises one or more video display units.

previewing the proof

22. A system as in claim 16 wherein captured images include images of portions of the live event and images of spectators and are combined to present composite images of the event and spectators.

23. A system as in claim 16 including a color printer to print captured images for spectators.

24. A system as in claim 16 wherein an image taking sequence can be initiated to execute a series of steps to take a continuous succession of images throughout at least a portion of the venue.

25. A system as in claim 16 wherein a spectator can select a desired image by seat location.

26. A system as in claim 16 wherein captured images are transferred to the central server by any one or more of disks, cartridge, transmitted via cable, wire, radio, infrared and satellite.

27. A system as in claim 16 including workstations whereby captured images can be manipulated using image editing software.

28. A system as in claim 16 wherein the spectators are of a sport venue venue.

29. A system in claim 16 wherein the spectators are of an entertainment venue.

* * * * *

US005531645A

United States Patent [19]

Collins

[11] **Patent Number: 5,531,645**

[45] **Date of Patent: Jul. 2, 1996**

[54] **AMUSEMENT RIDE**

[76] Inventor: **Laurence H. Collins**, 4 Enterprise Rd., Mablethorpe, United Kingdom

[21] Appl. No.: **380,352**

[22] Filed: **Jan. 30, 1995**

[51] **Int. Cl.**^{6} **A63G 13/06**

[52] **U.S. Cl.** **472/97**; 472/95; 354/290

[58] **Field of Search** 472/95, 96, 97, 472/98, 29, 6; 354/290, 291, 80

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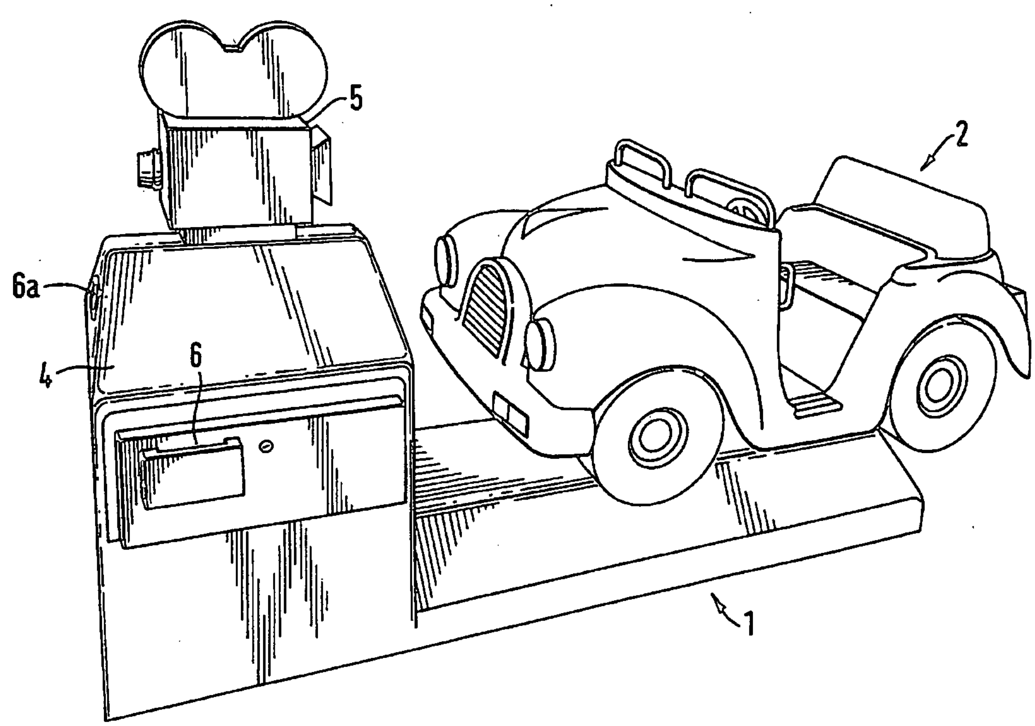
Primary Examiner—Kien T. Nguyen
Attorney, Agent, or Firm—Watov & Kipnes

[57] **ABSTRACT**

A coin or token-operated amusement ride comprises a base having a drive unit therein and one or more driven arms extending therefrom and supporting a ride seat which is moved cyclically for a period of ride operation by the drive unit upon actuation by payment of one or more coins or other tokens into the ride, wherein there is further provided a camera unit mounted on the ride and directed toward the ride occupant/user and adapted to be triggered during operation of the ride to take a photograph of the ride occupant. A printer may deliver the finished print to the ride occupant as the ride operation ends.

17 Claims, 8 Drawing Sheets



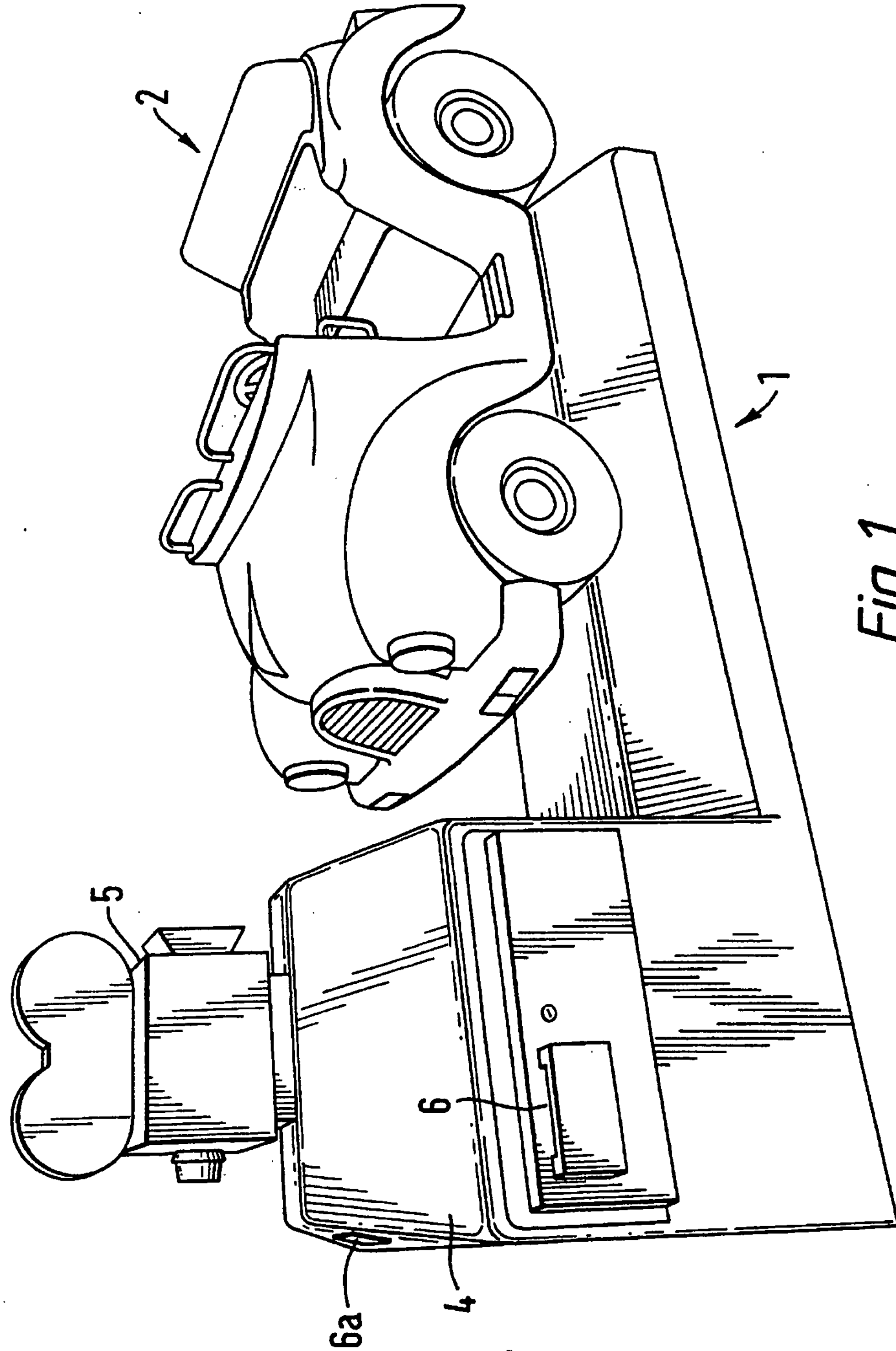


Fig. 1

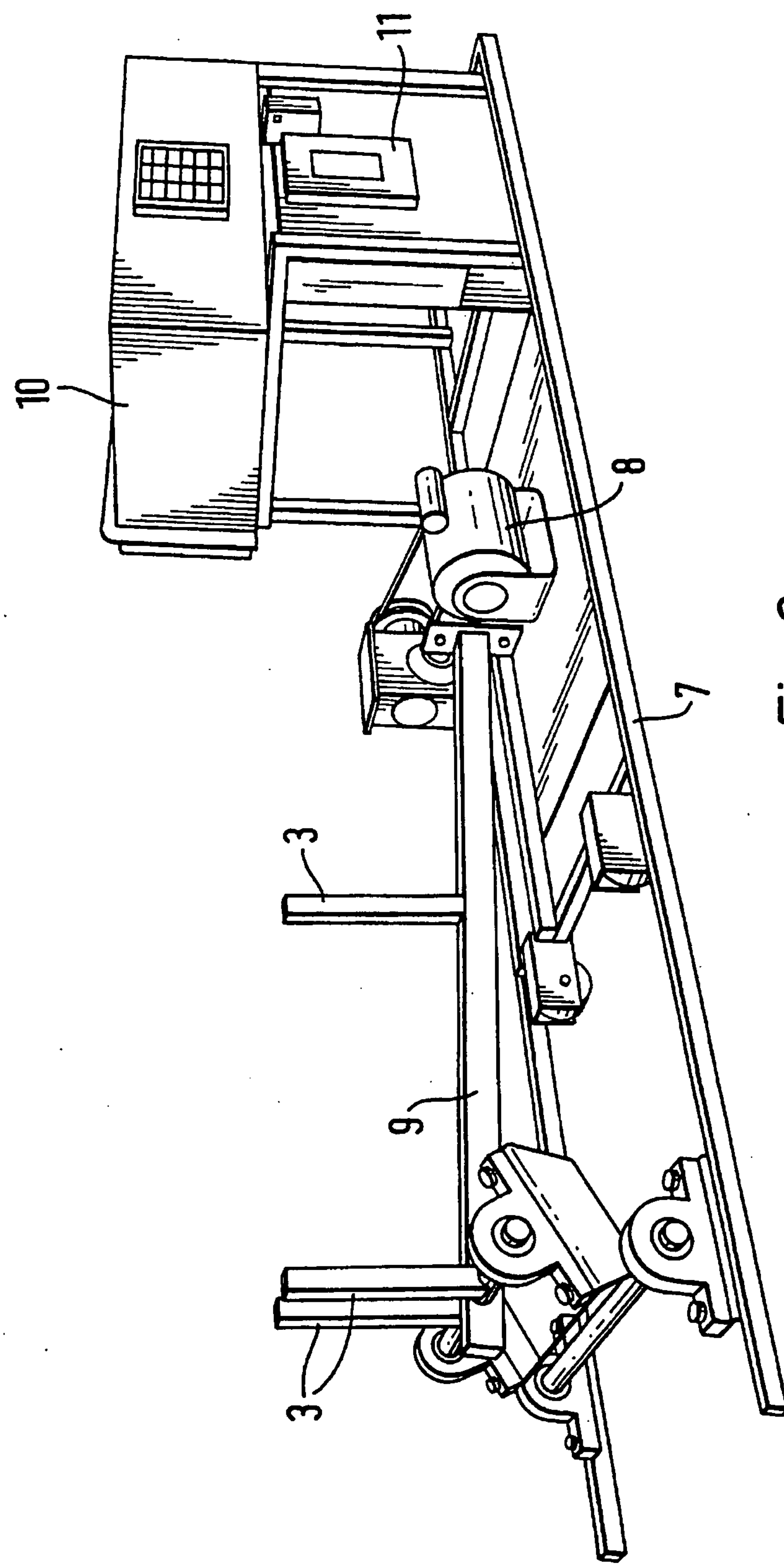


Fig. 2

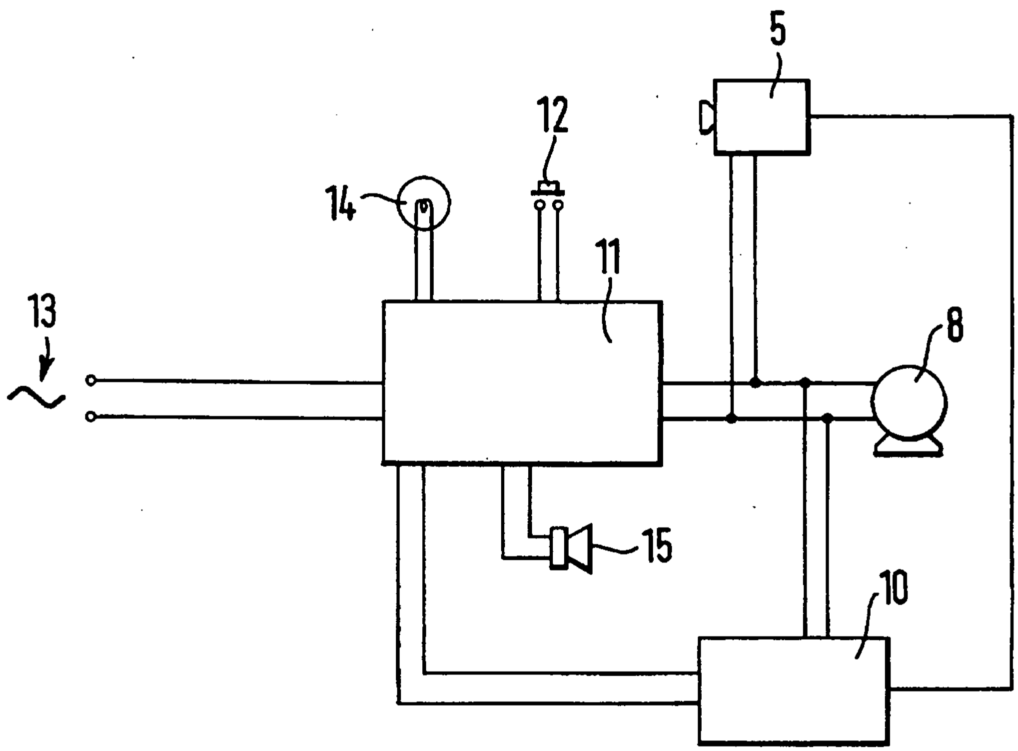


Fig. 3

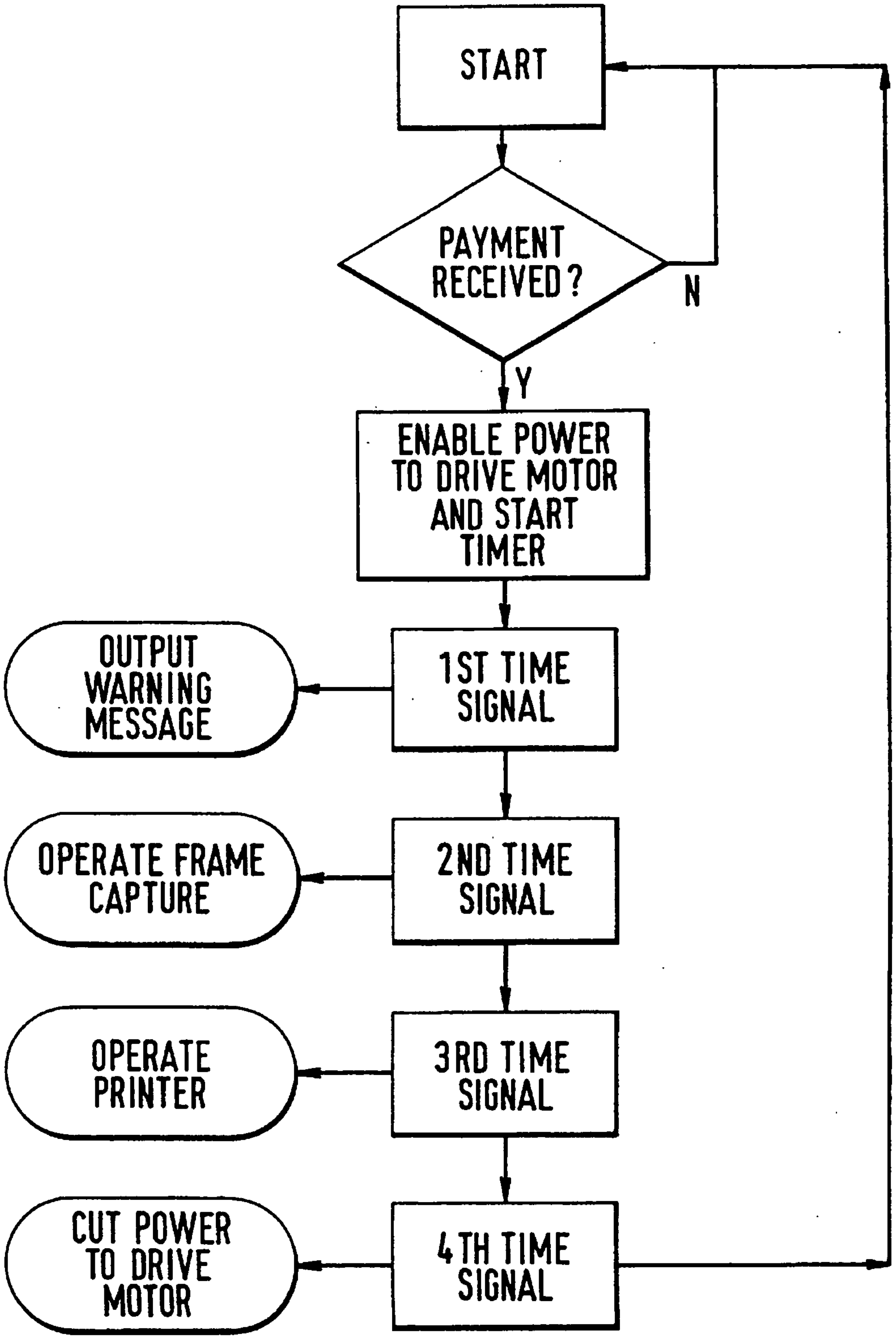

START
PAYMENT RECEIVED?
N
Y
ENABLE POWER TO DRIVE MOTOR AND START TIMER
1ST TIME SIGNAL
OUTPUT WARNING MESSAGE
2ND TIME SIGNAL
OPERATE FRAME CAPTURE
3RD TIME SIGNAL
OPERATE PRINTER
4TH TIME SIGNAL
CUT POWER TO DRIVE MOTOR

Fig. 4

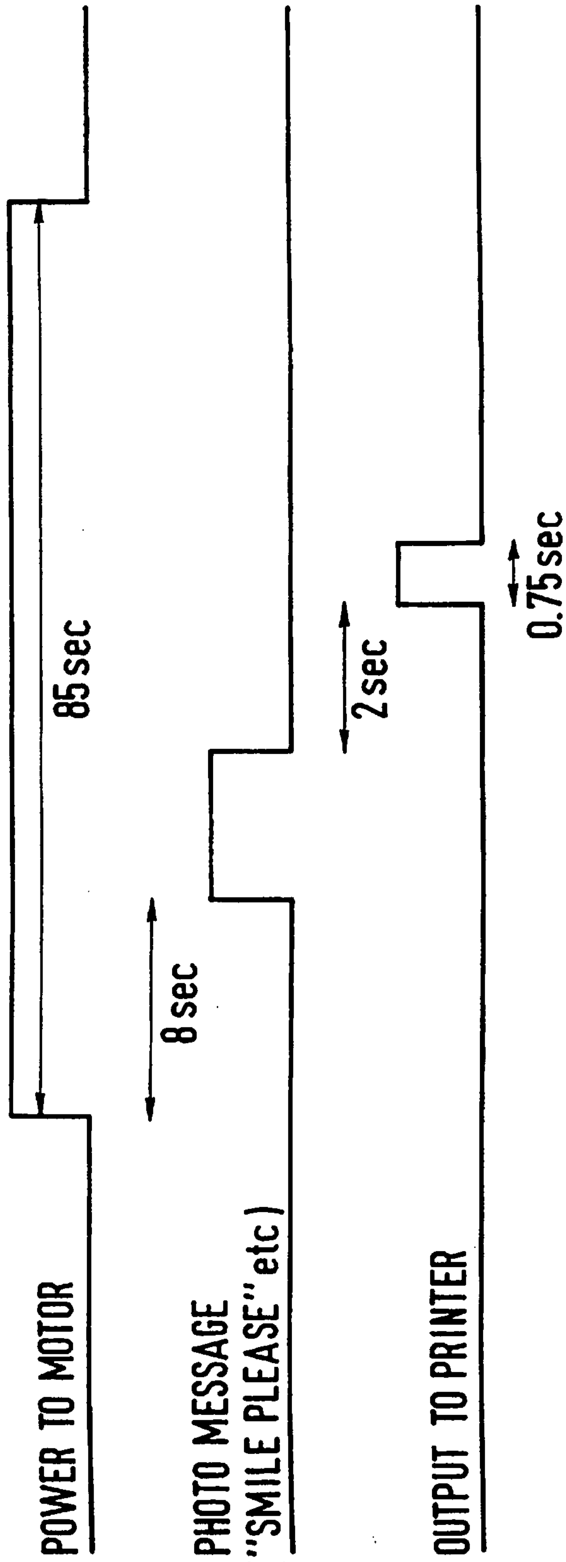

POWER TO MOTOR
PHOTO MESSAGE
("SMILE PLEASE" etc)
OUTPUT TO PRINTER
85 sec
8 sec
2 sec
0.75 sec

Fig.5

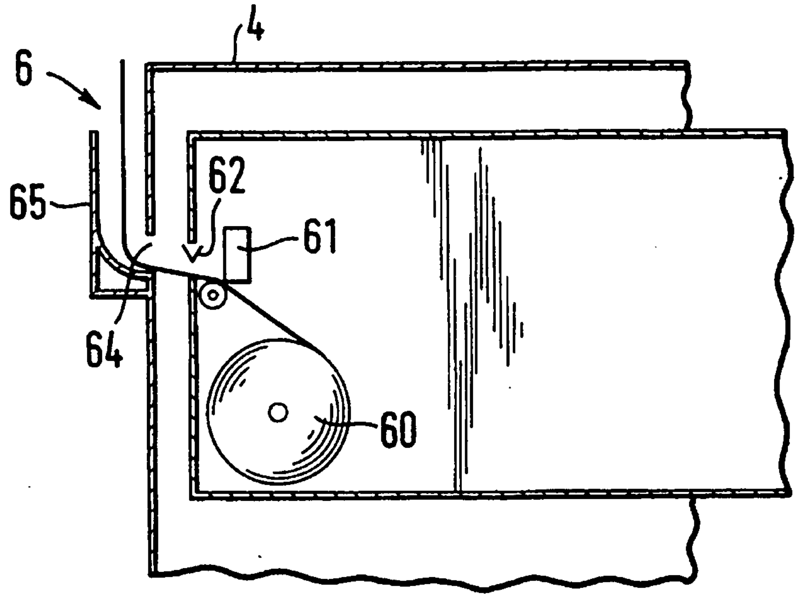


Fig. 6

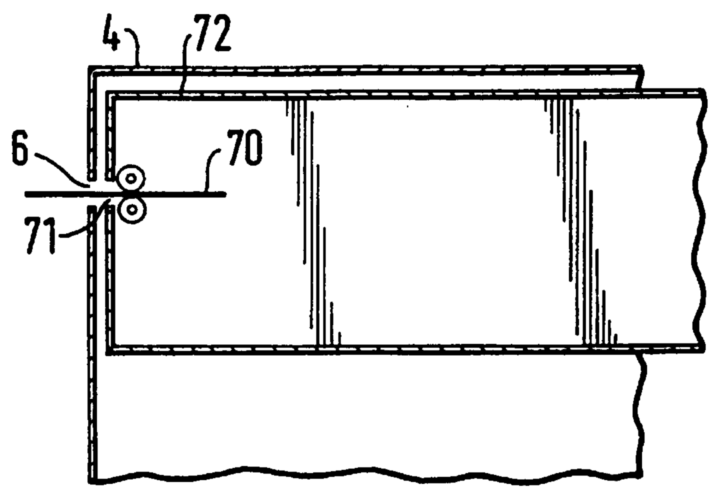


Fig. 7

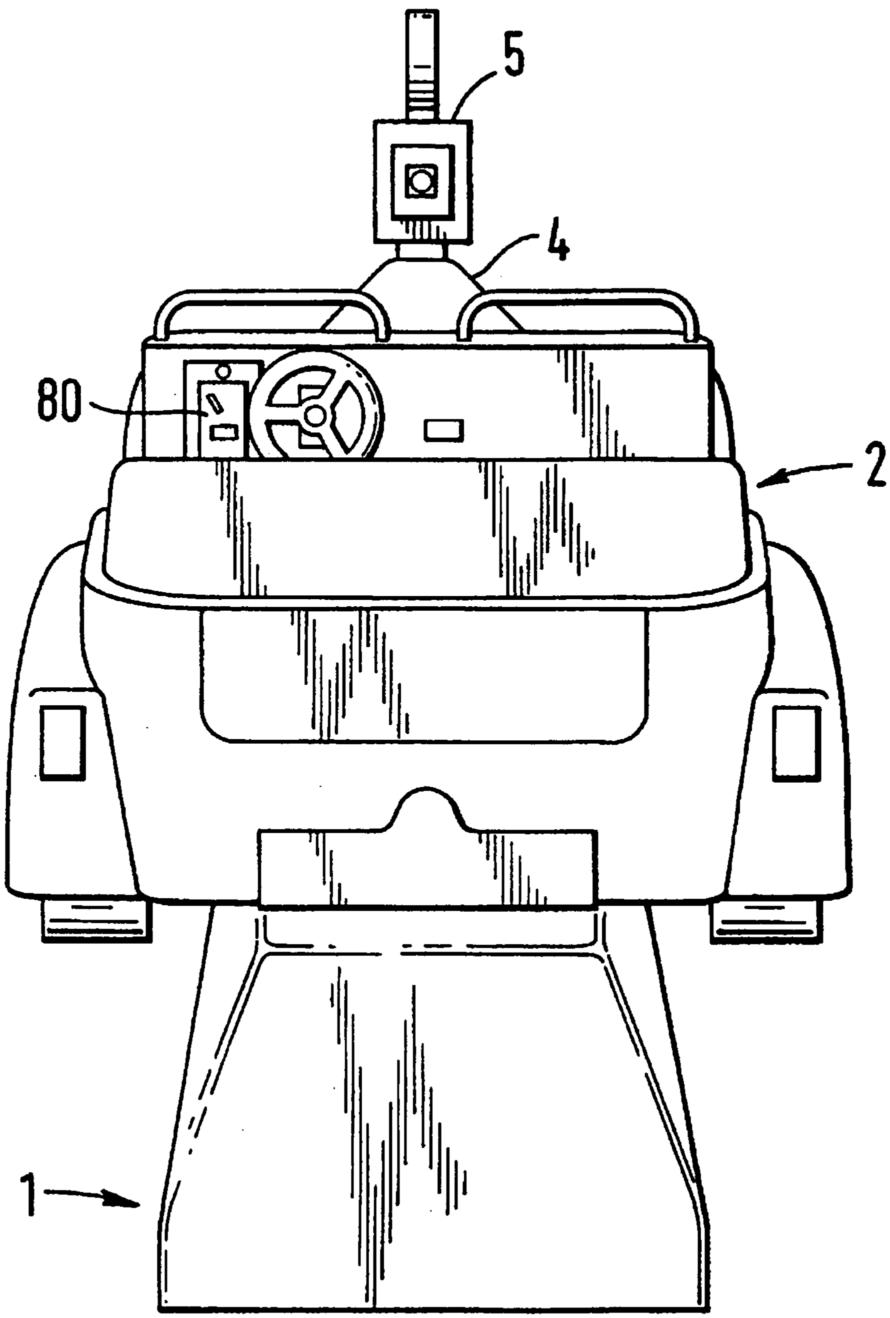


Fig. 8

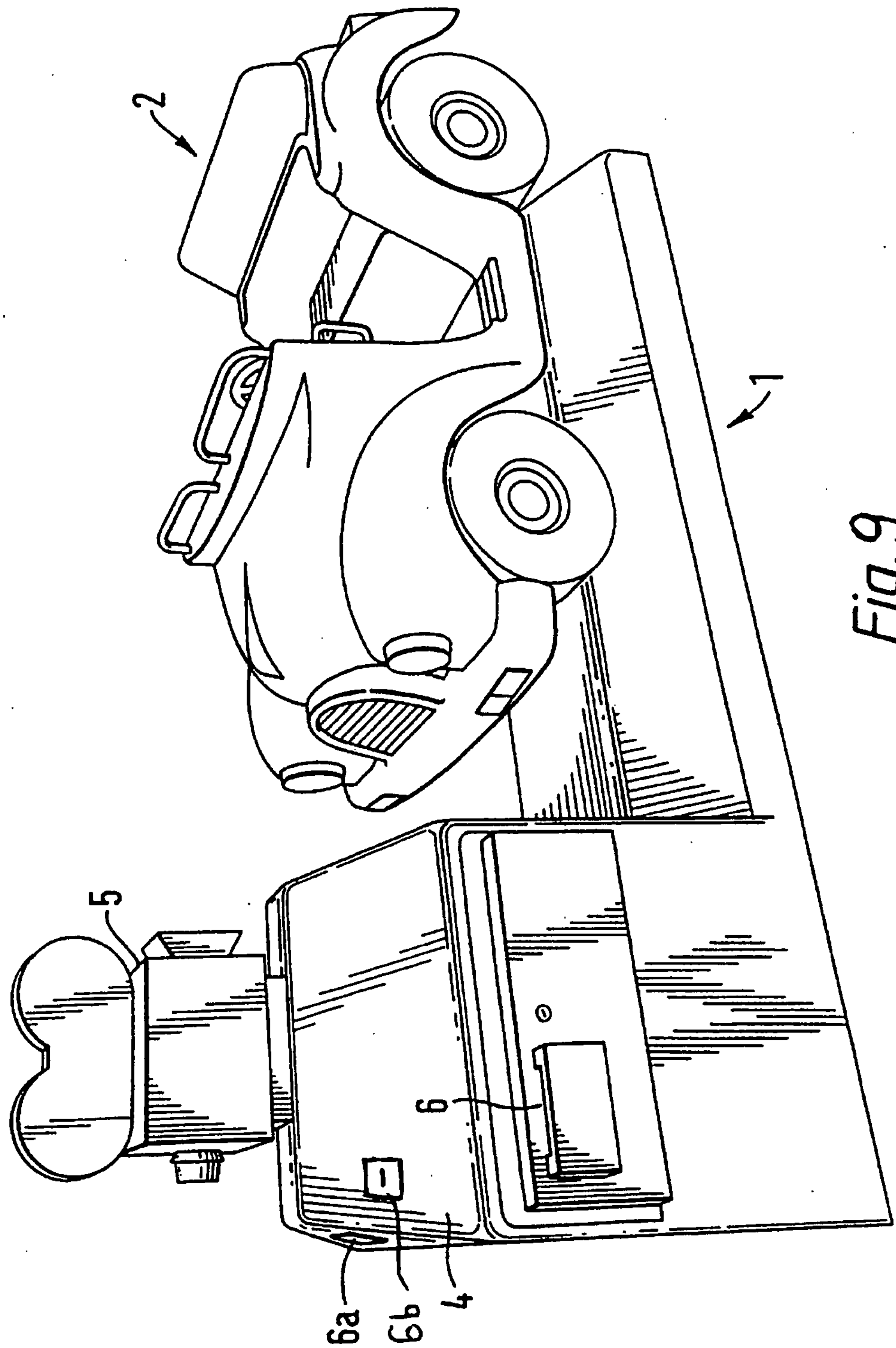


Fig.9

AMUSEMENT RIDE

FIELD OF THE INVENTION

The present invention relates to an amusement ride, for example of the type in which a child sits on or in a seat which is then moved cyclically for a predetermined period in response to receipt by the ride of a payment. Such rides are typically referred to as "kiddie rides".

BACKGROUND TO THE INVENTION

Coin-operated amusement rides are a familiar feature of many shopping precincts and amusement arcades throughout the United Kingdom and elsewhere in the world. The rides are generally compact electrically-powered devices comprising a base drive unit having a driven support arm extending upwardly therefrom and supporting a moulding of a suitable, generally fanciful, design, for example of a cartoon animal, a transport vehicle or other figure, and having a seat mounted thereon or formed integrally therewith. The support arm is generally arranged to oscillate to provide the seat with a cyclical fore-and-aft and/or up-and-down and/or side-to-side motion once the ride has been initiated by inserting the requisite number of coins or tokens into a pay box.

A recent development of the kiddie ride provides the user with a present, or "prize", as a further inducement to use the ride and/or as a memento, or as a method of vending articles such as toys in a novel way. In such systems the ride generally dispenses the present at the start or finish of the ride's session. Such a system is disclosed in GB-A-2 179 56 1.

As a memento of the ride, however, a novelty present has no special significance. It would be more desirable to provide a record of the experience.

SUMMARY OF THE INVENTION

According to the present invention there is provided an amusement ride comprising a base including drive means, a seat mounted on the base and movable relative thereto by the drive means, first payment means for causing operation of the drive means in response to receipt of a payment, photographic means attached to the base and arranged to produce a photograph of the seat and any occupant thereof, and control means operatively connected to the drive means and to the photographic means to enable operation of the photographic means when the drive means is operating.

Preferably the control means comprises timing means to cause the photographic means to operate automatically to produce a photograph after a predetermined period of operation of the drive means. Triggering of the photographic means to produce the photograph takes place as a result of operation of the drive means in response to receipt of payment, which may be by way of coins, tokens, notes, or magnetic or electronic payments cards or the like. The ride may incorporate synchronising means to ensure that the seat and its occupant are in a predetermined position relative to the photographic means to ensure that the best picture is achieved from the point of view of focus, lighting, movement of the subject and composition.

The ride may comprise means for generating a warning signal at a predetermined time interval before operation of the photographic means. The means for generating a warning signal preferably comprises speech synthesis means for

producing a speech message. A visible signal, such as a warning light or sign, may be produced as well or instead.

In an alternative embodiment of the invention, a second payment means is associated with the photographic means and arranged to cause operation of the photographic means in response to receipt of a payment therein. The second payment means may be a coin-release mechanism of the "lock-out" type, which requires a voltage signal to release it. The voltage signal can be provided by the power to the drive means, so that the mechanism can only be operated while the ride is operating. Alternatively, an electronic coin mechanism can be used, the mechanism only being powered while the drive is powered.

In yet another embodiment, the first payment means comprises an electronic coin-release mechanism arranged to provide two alternative control signals according to the value of the money or tokens inserted. For example, a first, lower, payment causes the mechanism to output a first control signal which in turn causes the control means to operate the drive means alone, while a second, higher, payment causes the mechanism to output a second control signal which in turn causes the control means to operate the drive means and the photographic means in the required sequence.

Preferably, the photographic means comprises a video camera outputting a succession of video frames representing photographic images, and printing means for capturing one of the frames and for producing a photographic print of the image represented by the frame. The printing means may be a video printer, for example of the type producing a monochrome image thermally or a colour image by a dye-sublimation process or the like. The operation of the printing means may be initiated by a timing signal from the control means, by a user-operated press-button, or by the second payment means, when fitted.

Alternatively, the photographic means may comprise a camera provided with photochemical imaging means operable to produce a photographic print during the operation of the drive means or within a predetermined period following the end of operation of the drive means. An example of a suitable photochemical imaging means is the "instant" film pack sold by Polaroid Corporation, although it would also be possible to use a more conventional film processing and printing system, for example of the type used in photographic booths and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be more particularly described by way of example with reference to, the drawings, in which:

FIG. 1 is a perspective view of a coin operated amusement ride in accordance with a preferred embodiment of the invention;

FIG. 2 is a perspective view from the rear of the ride illustrated in FIG. 1, with the casing removed;

FIG. 3 is a diagram illustrating the operative components of the ride;

FIG. 4 is a flow chart illustrating the sequence of events in the operation of the ride;

FIG. 5 is a timing chart for the operation of the ride;

FIG. 6 is a diagrammatic sectional view of part of the ride showing the delivery of the photograph from a monochrome printer;

FIG. 7 is a diagrammatic sectional view of part of the ride showing the delivery of the photograph from a colour printer;

FIG. 8 is a view from the rear of the seat unit of the ride shown in FIG. 1, but showing an alternative location for the coin mechanism; and

FIG. 9 is a view corresponding to that of FIG. 1, showing an alternative embodiment having two coin-slots.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Referring to FIG. 1, the ride comprises a base 1 containing a drive motor and control means as hereinafter described with reference to FIG. 2. A seat unit 2, in the form of a toy car, is mounted on drive arms 3 (FIG. 2) so as to be movable relative to the base. It will be appreciated that, while the seat unit is illustrated in the form of a toy car, it can have any other form, such as other vehicles and animals. The base 2 includes at one end thereof a control cabinet 4 mounting a video camera 5 directed toward the seat unit 2. The camera is suitably mounted within a protective casing, which can be shaped to simulate the appearance of an old movie camera or the like for decorative purposes. The cabinet 4 has at one side a delivery slot 6 for finished photographs and at the end a coin-slot 6*a* to operate the ride.

Referring now to FIG. 2, the base 2 has a support frame 7 on which is mounted an electric motor 8 driving a reciprocating beam 9 which in turn carries the drive arms 3 on which the seat unit 2 is mounted. The reciprocating beam 9 imparts to the seat unit 2 an up-and-down and forward-and-backward motion. The cabinet 4 includes within it a video printer 10 connected to the video camera 5 and arranged to capture a video frame from the camera in response to a control signal and to print the frame as a photograph to be output to the delivery slot. The video camera may be a monochrome camera, for example a Sony SSC M350 CE monochrome video camera, the video printer then being, for example, a thermal printer forming a monochrome image on heat-sensitive paper. Alternatively, the video camera 5 may be a colour camera, for example a Mitsubishi CCD-200 colour video camera, and the printer is then a colour printer, for example of the dye-sublimation type, such as that sold by the Sony Corporation under their designation UP 1200 EPM. Such printers are capable of producing a full-colour finished photograph within the duration of a typical kiddie ride, i.e. within 60 seconds. The cabinet 4 also mounts a microprocessor-based controller 11 and contains a secure coin receiver (not shown) for the coin-release mechanism.

Any of a wide range of suitable controllers may be used. A particularly preferred controller is manufactured by the UK company Integrated Technology Limited and is designated the Sound Master Control Unit SMVS 2.01. This device has a high level of programmability and incorporates speech message circuitry and a wide range of hardware control outputs, including the necessary outputs to control a video camera and video printer.

FIG. 3 illustrates the working relationship between the various components of the ride. The controller 11 is connected to an AC mains supply 13 (230 V 50 Hz in the UK), and provides a switched mains power output to the electric motor 8, the camera 5 and the printer 10, so that the latter two items can only operate when the motor is running. A control signal input from the coin-release mechanism 12 serves to initiate operation of the ride, and outputs are provided from the controller 11 to the printer 10, to a warning light 14 and to a loudspeaker 15.

The operation of the ride will now be described with reference also to the flow chart shown in FIG. 4. The illustrated ride incorporates a colour printer, but the operation of a ride having a monochrome printer is essentially very similar. The controller 11 repeatedly monitors the output from the coin-release mechanism. Upon receipt of a signal indicating that the correct payment has been made, the controller 11 switches mains power to the motor 8 and to the video camera 5 and printer 10. A timer within the controller is started. The timer is arranged to output time signals at predetermined intervals after the start of the ride's operation (i.e. from the switching of power to the motor 8). At the first time signal, the controller 11 switches on a lamp to illuminate a warning sign to indicate that the picture is about to be taken. The sign may carry words such as "Smile Please" or "Say Cheese" or the equivalent in the local language, or it may carry a symbol, for example of a camera. The sign may be illuminated continuously or intermittently (flashing) for a predetermined period. At the same time, speech generating circuitry within the Integrated Technology SMVS 2.01 controller outputs a speech warning to the loudspeaker 15, for example repeating the words mentioned above in relation to the warning sign.

After a suitable delay, the second time signal is output from the timer, and this in turn causes the controller to send a control signal to the video printer 10 to cause it to capture a video frame from the video camera 5. A third time signal then causes a second control signal to be sent by the controller to the video printer 10 to start the printing operation for the captured frame. The finished print is then delivered to the slot 6 after a standard processing time,as hereinafter described with reference to FIGS. 6 and 7.

The time signals are arranged such that the interval between the third time signal and the fourth time signal, which causes the controller to switch off the power to the motor 8, thus ending the ride operation, is sufficient to ensure that the photograph is delivered during or at the end of the ride's operation, or with only a very short delay after the movement ceases, so as to ensure maximum availability of the ride. It will be appreciated that the microprocessor in the controller can be programmed to ensure that the time signals are sent at the desired intervals.

Typically with a monochrome printer, and with some colour printers, only one control signal is required to cause the photographic print to be produced; the separate frame capture and print steps are combined. This is illustrated in FIG. 5, in which the times intervals are not to scale. It will be appreciated that the timings shown in FIG. 5 are merely examples; they can be varied without affecting the scope of the invention.

Referring to FIG. 6, the monochrome printer includes a roll 60 of thermally-sensitive paper which, during the printing operation is passed over a thermal printing head 61 to form the monochrome photographic image, the desired length of paper being cut off by a cutter 62 after emerging through an opening 64 in the cabinet 4 and being deflected upwardly by a deflector 65 to be delivered to the slot 6.

An alternative arrangement is used in the case of the colour printer, as illustrated in FIG. 7. Here, the dye-sublimation material is held in the printer in the form of individual sheets 70 which are delievred by the printer's drive mechanism through a slot 71 in the casing 72 of the printer, the slot 71 being aligned with the slot 6 in the cabinet 4.

In an alternative arrangement, illustrated in FIG. 8, the coin-release mechanism 80 is mounted in the seat unit, so that the child can cause its operation by insertion of the coins itself. In this arrangement, the electronic coin-release

mechanism used needs to be level when operated, and it is therefore important to ensure that the ride is stopped with the mechanism level. This is conventionally achieved by the provision of magnetic switches or the like which send out a signal when the ride passes a predetermined point, the power to the motor being cut at this point or within a predetermined interval afterwards. In order to ensure that the seat and its occupant are in the optimum position within the field of view and focus of the video camera, this signal may alternatively be used to trigger the operation of the frame capture step (or the printing step in the case of a monochrome printer), the controller being arranged to look for the signal from the magnetic switch after the second time signal is output, and to send the control signal to the printer at an interval after receipt of the magnetic switch signal such as to ensure that the seat unit and its occupant arrive at the optimum position at the same time as frame capture occurs.

FIG. 9 illustrates an alternative embodiment to that shown in FIG. 1, in which a second coin-release mechanism **6b** is also provided to cause operation of the photographic means in response to receipt of a payment therein. The second coin-release mechanism can only be operated while the ride is operating.

I claim:

1. An amusement ride comprising a base including drive means and a seat mounted on the base and movable relative thereto by the drive means, first payment means for causing operation of the drive means in response to receipt of a payment, photographic means attached to the base and arranged to produce a photograph of the seat and any occupant thereof, and control means operatively connected to the drive means and to the photographic means to enable operation of the photographic means when the drive means is operating.

2. An amusement ride according to claim **1**, wherein the control means comprises timing means to cause the photographic means to operate to produce a photograph after a predetermined period of operation of the drive means.

3. An amusement ride according to claim **2**, comprising means for generating a warning signal at a predetermined time interval before operation of the photographic means.

4. An amusement ride according to claim **3**, wherein the means for generating a warning signal comprises speech synthesis means for producing a speech message.

5. An amusement ride according to claim **1**, comprising a second payment means associated with the photographic means and arranged to cause operation of the photographic means in response to receipt of a payment therein.

6. An amusement ride according to claim **5**, wherein said second payment means comprises a coin- or token-release mechanism.

7. An amusement ride according to claim **5**, wherein said second payment means comprises a note-acceptor mechanism.

8. An amusement ride according to claim **5**, wherein said second payment means comprises a card-reading device for payment cards.

9. An amusement ride according to claim **1**, wherein the photographic means comprises a video camera outputting a succession of video frames representing photographic images and printing means for capturing one of the frames and for producing a photographic print of the image represented by the frame.

10. An amusement ride according to claim **1**, wherein the photographic means comprises a camera provided with photochemical imaging means operable to produce a photographic print during the operation of the drive means.

11. An amusement ride according to claim **1**, wherein the photographic means comprises a camera provided with photochemical imaging means operable to produce a photographic print within a predetermined period following the end of operation of the drive means.

12. An amusement ride according to claim **1**, wherein said first payment means comprises a coin- or token-release mechanism.

13. An amusement ride according to claim **1**, wherein said first payment means comprises a note-acceptor mechanism.

14. An amusement ride according to claim **1**, wherein said first payment means comprises a card-reading device for payment cards.

15. An amusement ride according to claim **1**, wherein a driven arm extends from the drive means to support the seat, the arm being moved cyclically for a period of ride operation.

16. An amusement ride according to claim **1**, wherein a plurality of driven arms extend from the drive means to support the seat, the arms being moved cyclically for a period of ride operation.

17. An amusement ride according to claim **1**, wherein means are provided for sending out a signal to the control means when the ride passes a predetermined point, and wherein the control means is arranged to enable operation of the photographic means at a predetermined interval after receipt thereby of said signal.

* * * * *

US005346210A

United States Patent [19]

Utke et al.

[11] Patent Number: 5,346,210

[45] Date of Patent: Sep. 13, 1994

[54] OBJECT LOCATOR SYSTEM

[75] Inventors: Reinhold E. Utke; John L. Eidsness; Dale P. Van de Loo; Gary L. Ellingson, all of Moorhead, Minn.; Joel T. Aslakson, Fargo, N. Dak.

[73] Assignee: Teem Systems, Inc., Moorhead, Minn.

[21] Appl. No.: 937,477

[22] Filed: Aug. 28, 1992

[51] Int. Cl.[5] A63B 61/00

[52] U.S. Cl. .... 273/55 R; 273/32 B; 273/372; 273/29 A; 367/6; 367/118; 342/450; 342/463; 340/323 R

[58] Field of Search .... 273/55 R, 32 B, 372, 273/29 RA; 367/6, 118, 124–127; 342/450, 451, 146, 465, 463; 340/323 R

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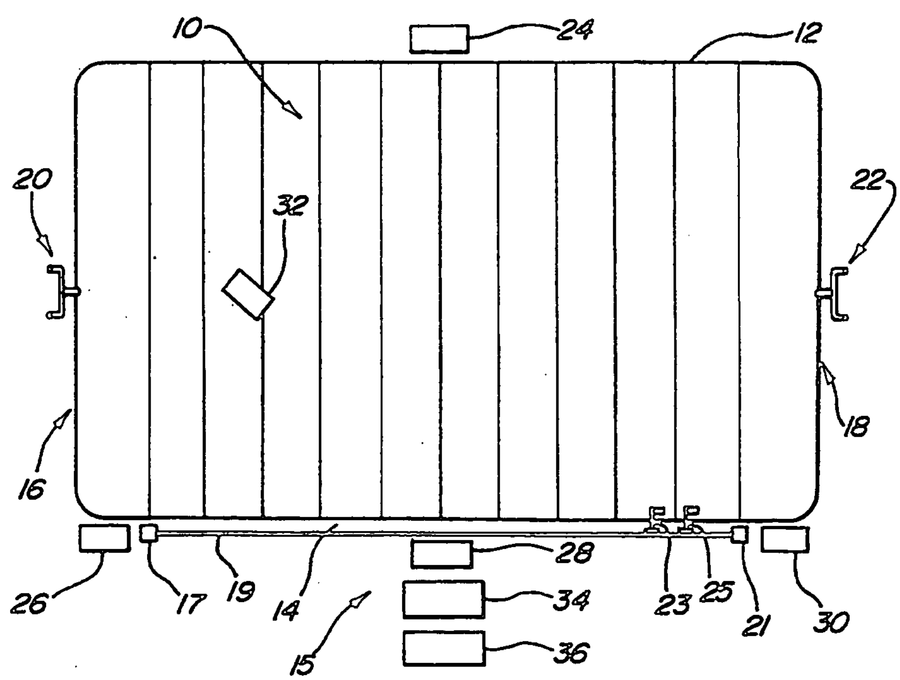
Primary Examiner—Vincent Millin
Assistant Examiner—Kerry Owens
Attorney, Agent, or Firm—Harness, Dickey & Pierce

[57] ABSTRACT

An object locating system, especially for use in locating a gaming ball in the game of football, utilizes a series of three sensors positioned on one side of a football playing field and a calibration source positioned on the other side. The calibration source emits an ultrasonic signal which is received by the sensors in order to provide a calibration signal. A ball marking unit is positionable on the field at a location of the ball and emits an ultrasonic signal which is received by the sensors and an RF signal which is received by the calibration source in order to turn the calibration source off. The sensors provide signals in which a processing unit calculates time delays by a time acquisition process in order to determine the position of the ball. In an alternate embodiment, the ball marking unit emits only an RF signal which is received by the sensors. The sensors again provide signals which are analyzed by the processing unit to determine delay between receipt of the signals at the sensors. Additionally, an automatic ball marking unit on a track drive can be controlled by the processing unit to automatically provide a visual representation of the ball's location.

31 Claims, 8 Drawing Sheets



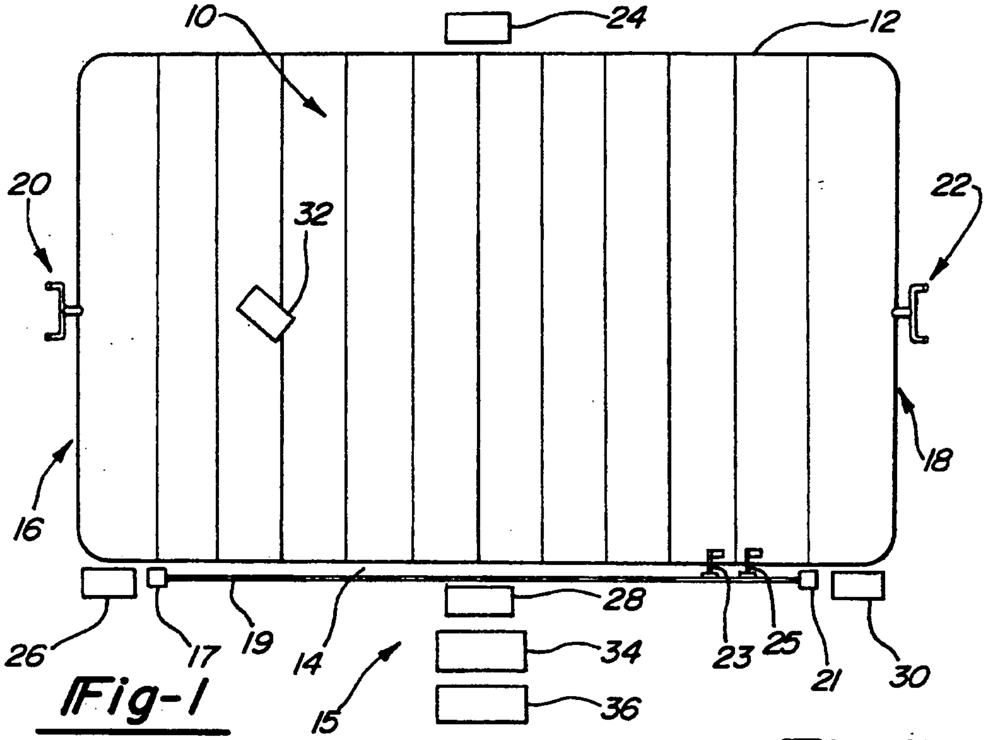


Fig-1

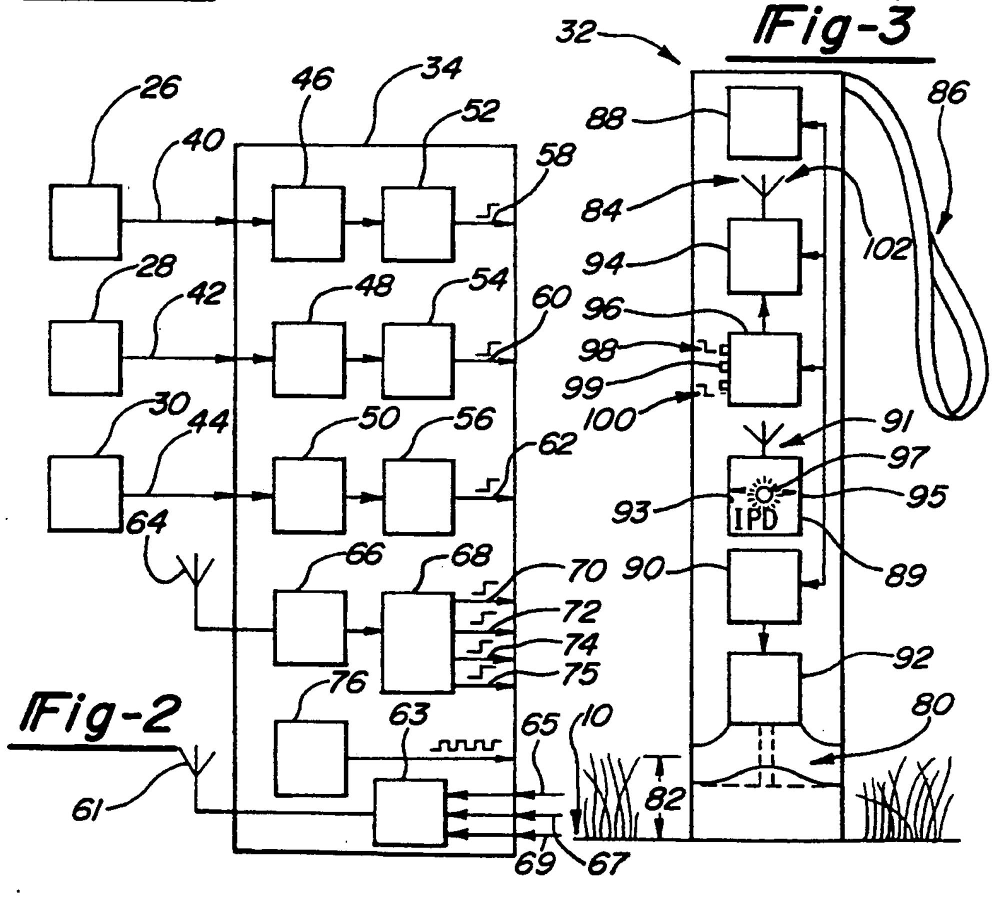


Fig-3

Fig-2

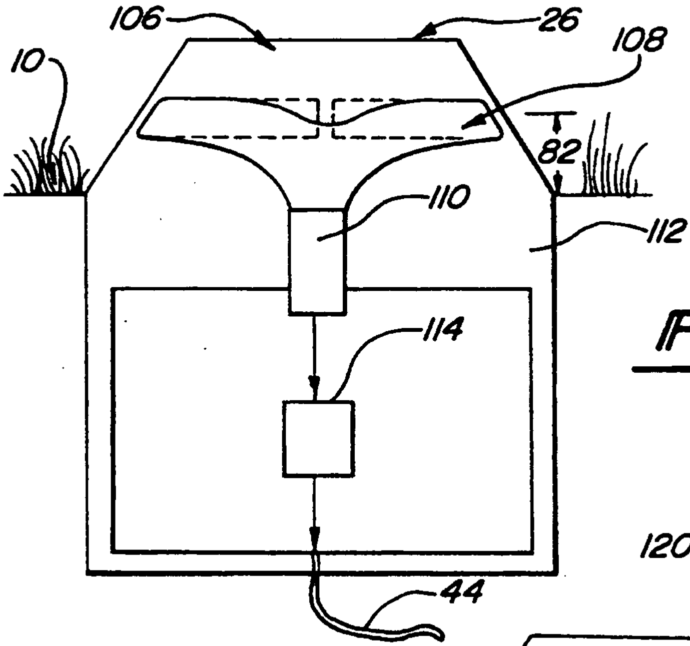


Fig-4

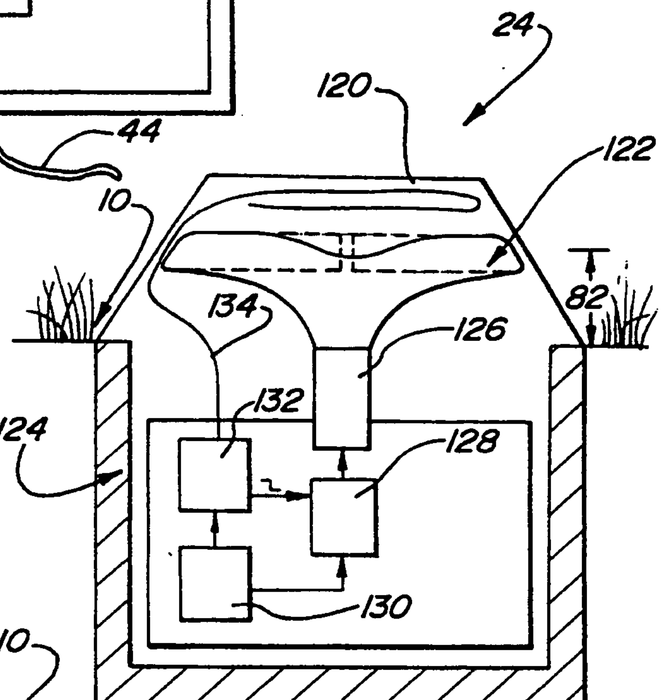
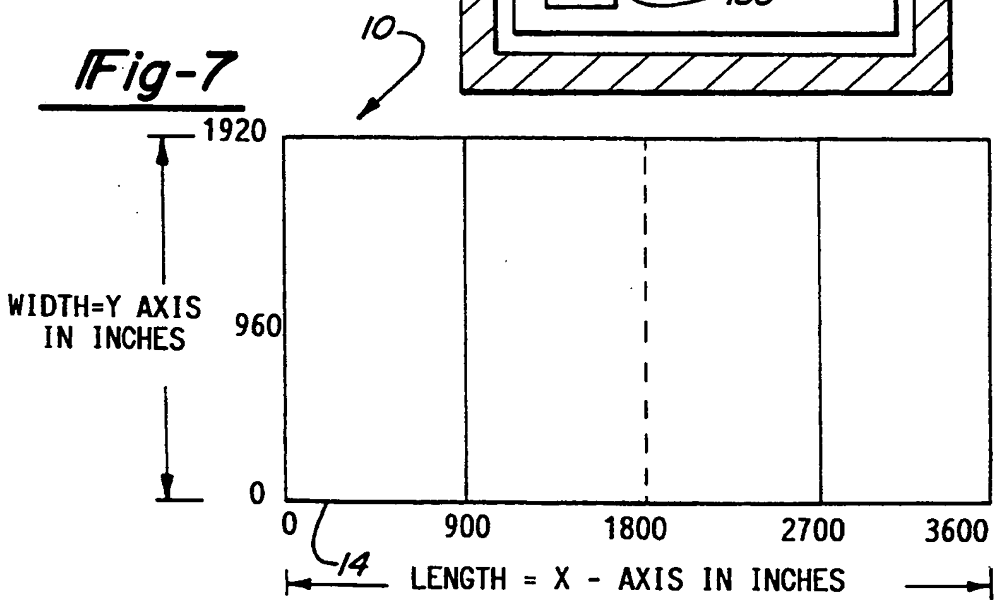


Fig-5

Fig-7



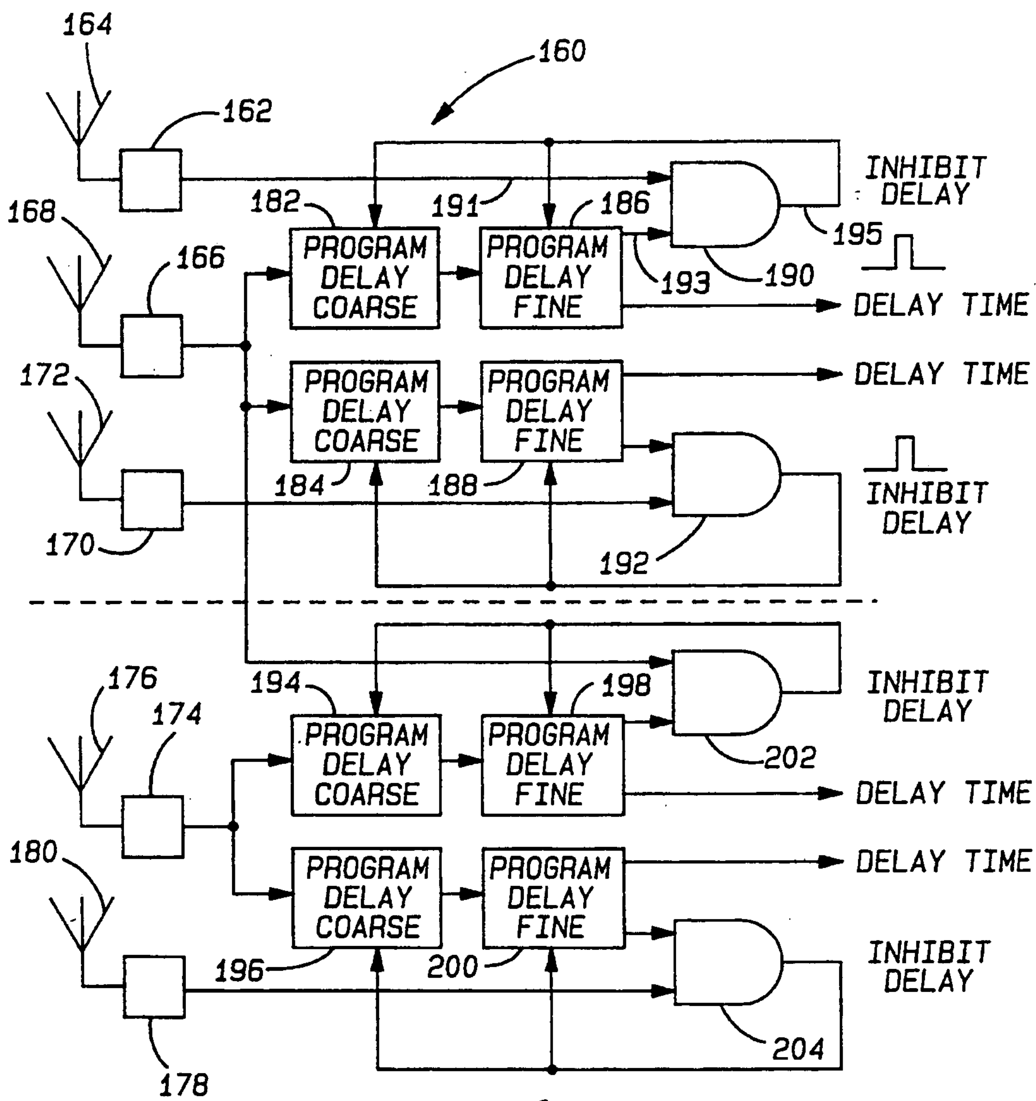

164
160
162
168
182
191
186
INHIBIT DELAY
195
166
PROGRAM DELAY COARSE
PROGRAM DELAY FINE
193
190
DELAY TIME
172
PROGRAM DELAY COARSE
PROGRAM DELAY FINE
DELAY TIME
184
188
INHIBIT DELAY
170
192
176
194
198
INHIBIT DELAY
174
PROGRAM DELAY COARSE
PROGRAM DELAY FINE
202
DELAY TIME
180
PROGRAM DELAY COARSE
PROGRAM DELAY FINE
DELAY TIME
196
200
INHIBIT DELAY
178
204

Fig-6a

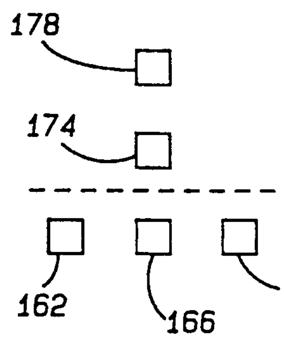

178
174
162
166
170

Fig-6b

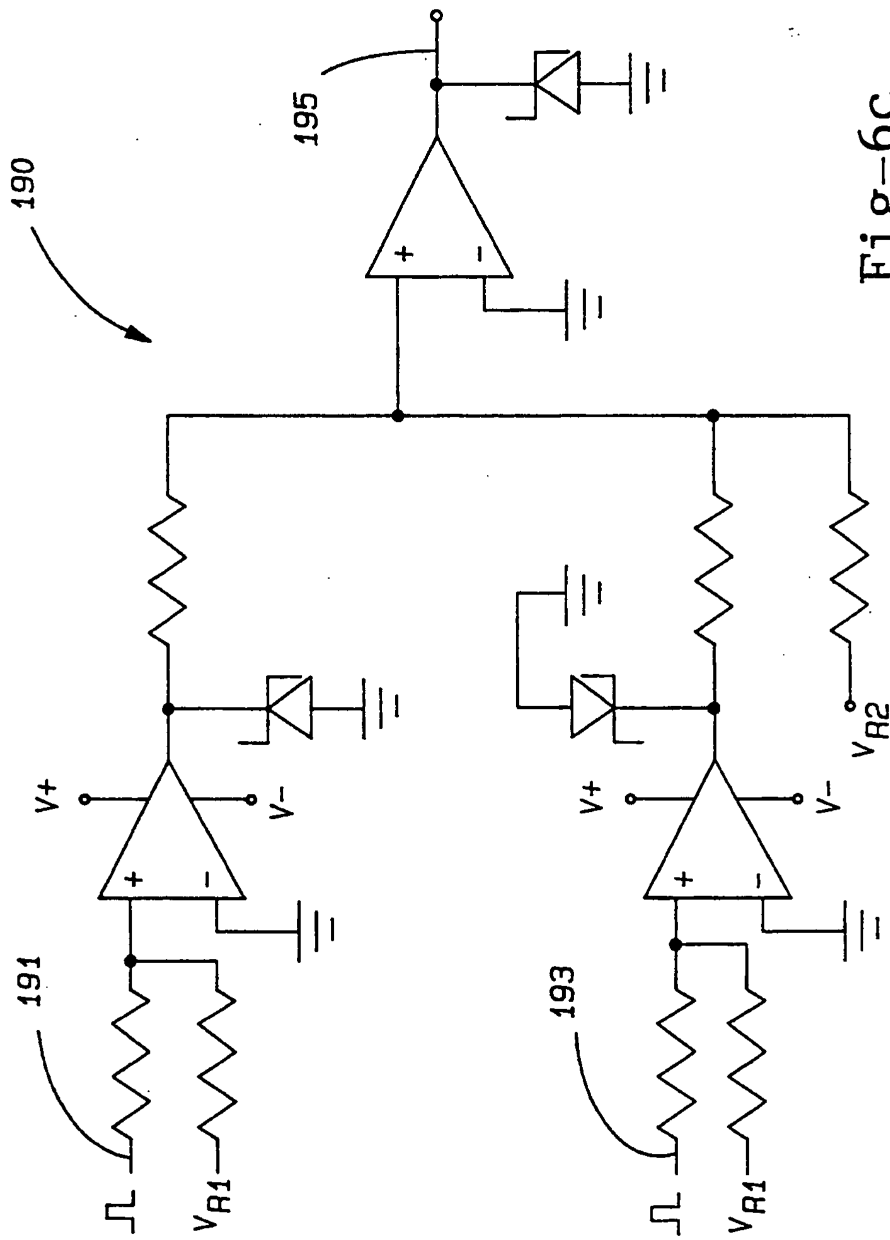


Fig-6c

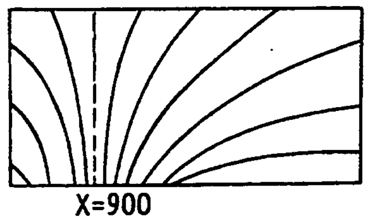


Fig-8A

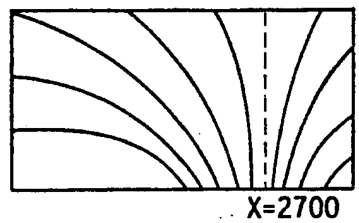


Fig-8B

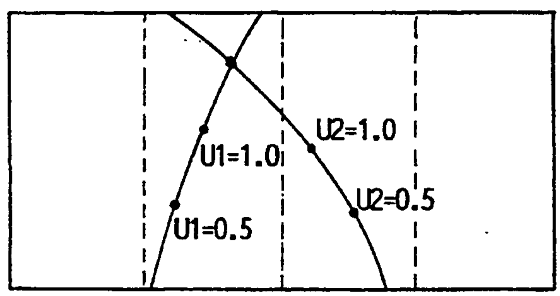


Fig-9

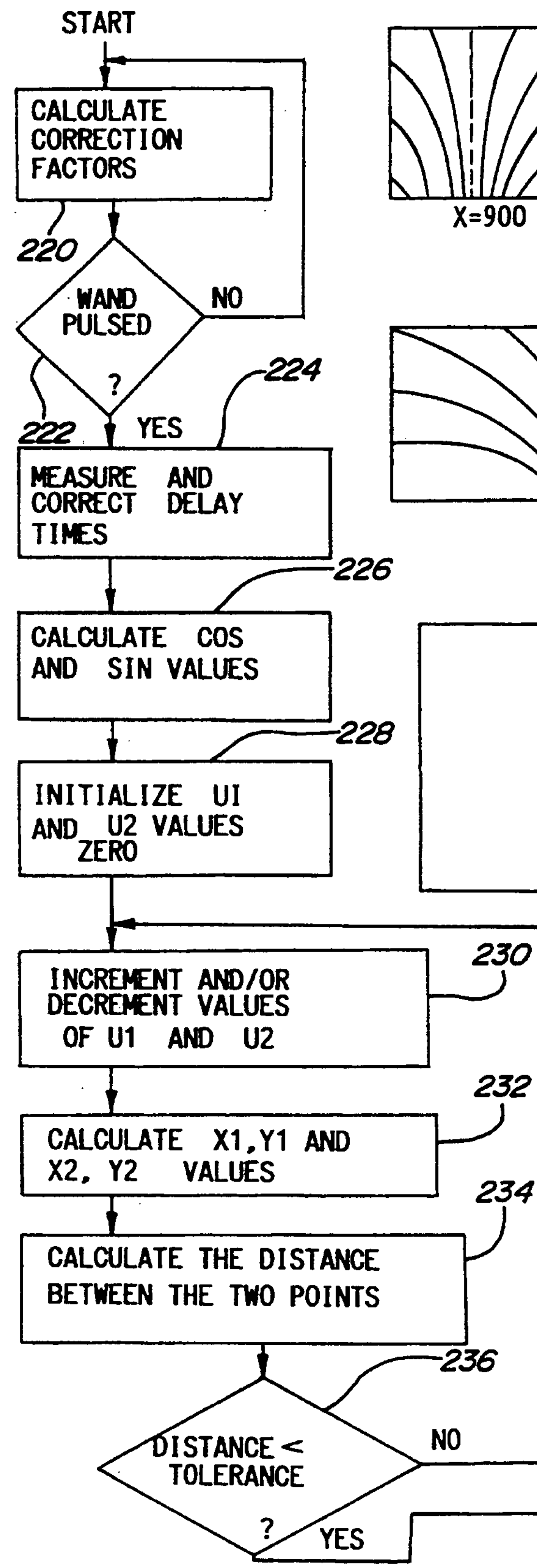


Fig-10A

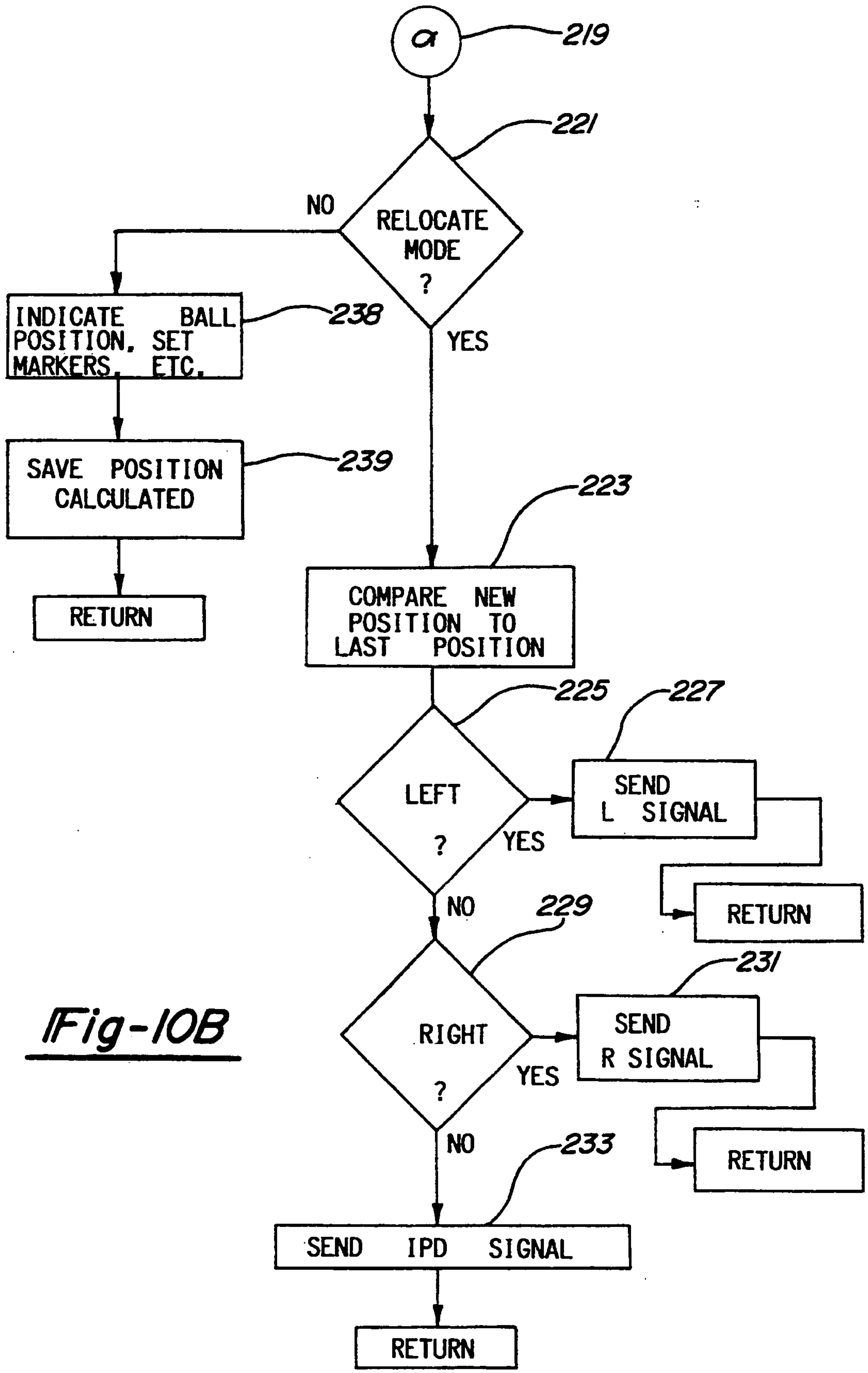

a
219
221
RELOCATE MODE ?
NO
YES
INDICATE BALL POSITION, SET MARKERS, ETC.
238
SAVE POSITION CALCULATED
239
RETURN
223
COMPARE NEW POSITION TO LAST POSITION
225
227
LEFT ?
YES
SEND L SIGNAL
RETURN
NO
229
231
RIGHT ?
YES
SEND R SIGNAL
RETURN
NO
233
SEND IPD SIGNAL
RETURN

Fig-10B

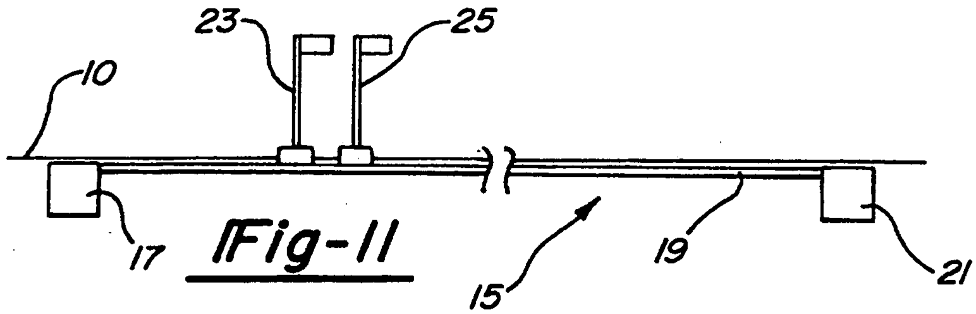


Fig-11

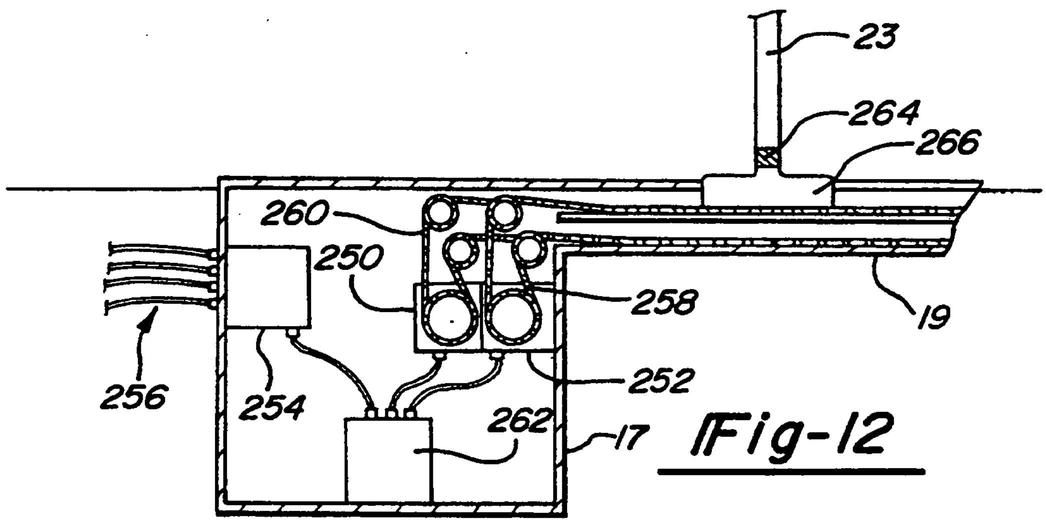


Fig-12

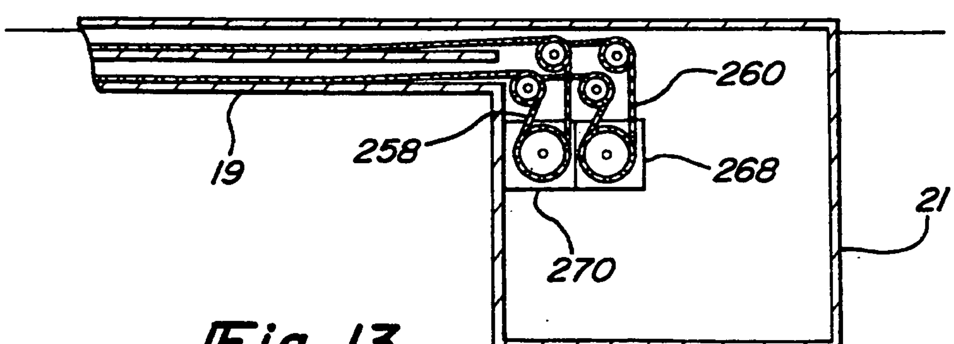
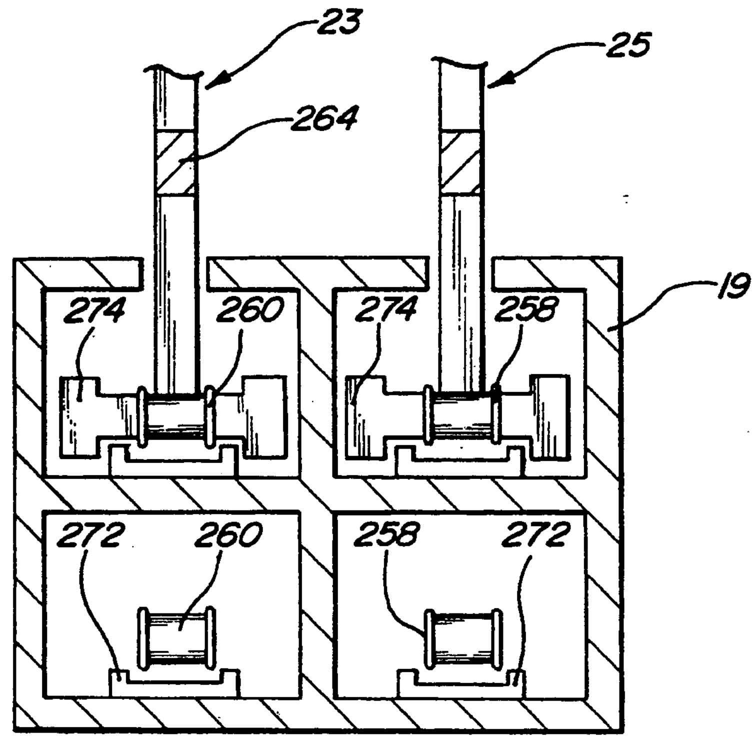


Fig-13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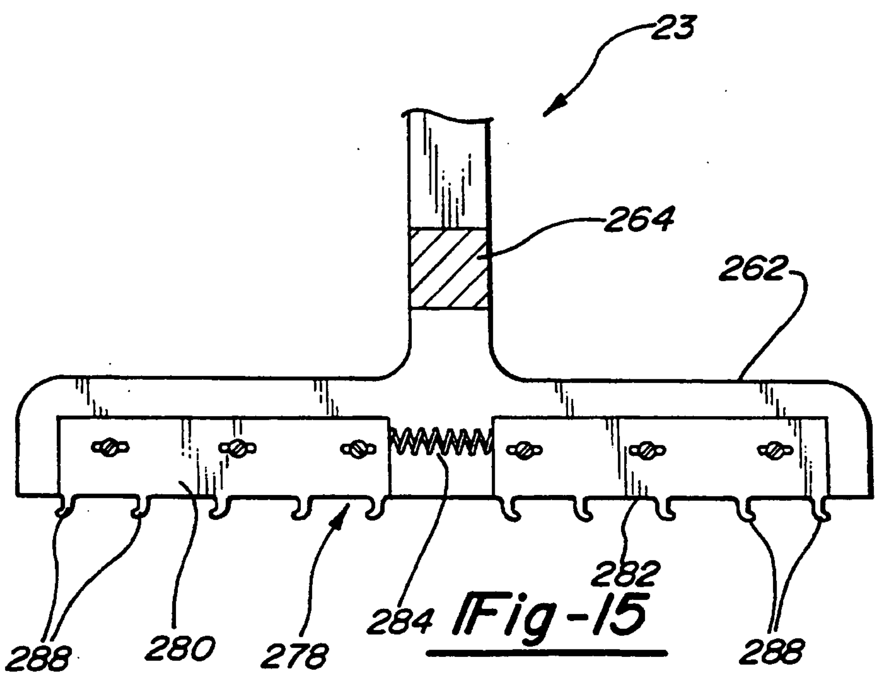
272

Fig-14


23
264
262
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284
282
288

Fig-15

OBJECT LOCATOR SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to systems for locating an object and, more particularly, to systems for determining the position of a gaming ball relative to a playing field by use of radio frequency and ultrasonic transmitters and receivers.

2. Discussion of the Related Art

In certain games incorporating gaming balls, it is generally crucial to the fairness of the game that the location of the gaming ball be reasonably accurately determined relative to a playing field. Typically, multiple gaming officials are utilized for determining the ball's location, and thus, a certain amount of subjectivity is interjected into the game which may result in substantial mistakes due to human nature possibly affecting the fairness of the play. With particular reference to football, it is necessary to determine the location of the football so as to enable the officials to accurately monitor "first down" situations, as well as, repositioning the football relative to a previous location. Additionally, the speed at which the game is played may be substantially affected by how quickly the gaming ball can be accurately located. Furthermore, the number of gaming officials necessary to officiate the game may also be substantially dependent on the ability of the officials to accurately determine the ball location. Therefore, different methods have been employed to at least assist the gaming officials in determining the location of the gaming ball.

Current technology has seen the use of instant-replay video equipment utilized for immediate reevaluation of close game play. This method, however, requires the interaction between gaming officials and broadcast technicians and involves the use of expensive cameras and video equipment not normally available at most sporting events. Additionally, stop-action photography equipment has been used to record photo-finish events. This method, while providing a permanent record, introduces additional time delay into the particular sporting event unless used in conjunction with instant replay video equipment, and therefore, would be subject to the same disadvantages as mentioned above. Further, photosensitive devices have been installed at appropriate locations which are triggered when a gaming ball or other apparatus or player crosses marked boundaries. This method is, however, restricted to boundary locations and does not address the game ball's location during the vast majority of play when the ball is at random locations and not at or crossing a boundary. Also, buried wires have been placed on field boundaries to magnetically detect a modified game ball as it passes over marked boundaries. This method, similar to the photosensitive devices described above, also requires modification of the gaming ball or other apparatus restricting the use of commonly available sporting devices and subjecting the devices to the rigors of the game.

The use of ultrasonic devices to measure distances is known. Ultrasonic measurement is, however, generally dependent upon consistent transducer coupling to the surrounding environment and the relative stability of that environment. Inconsistent results occur because ultrasonic waves will change under different environmental conditions as the sound waves pass through various media. Furthermore, playing field conditions could dynamically change over the playing season as a result of climatic variances, and even change during a single game itself due to player activity or changes in weather. Because playing field conditions can vary greatly, successful coupling of the transducers to the environment would be difficult to consistently achieve. In order to accommodate these environmental changes, sophisticated calibration methods of guaranteeing continued accuracy would have to be employed, thus increasing the cost and complexity of the system and sending the system beyond the reach of the resources of average schools and athletic departments. Consequently, the use of ultrasonics in ball locator systems has heretofore been limited.

Because of the limitations of sound waves as just discussed, it has been known to use radio frequency systems as gaming ball locators. Since radio frequency waves travel at very high speeds, environmental conditions have little effect on the wave propagation. One prior art football locating system using radio frequency waves is disclosed in U.S. Pat. No. 4,675,816 issued to Brandon, et al. That patent discloses a ball locator system in which a gaming official positions a radio transmitter at the football's location and then energizes the transmitter to send a radio signal to a series of rotating antennas positioned at predetermined locations relative to the playing field. The antennas "home" in on the transmitted signal and through the use of triangulation principles, the position of the football is determined relative to the playing field.

The above described radio frequency ball locator, as well as other radio frequency ball locators, suffer from a number of limitations and drawbacks. Because of the relatively small area of the playing field in comparison to the speed of the signal, the accuracy obtainable by the system would be limited due to the effective beam width of the radio frequency signal. In other words, because a greater portion of the beam width would be of a sufficient magnitude for the antennas to home in on, a certain degree of unacceptable tolerance would induce sufficient errors in the calculations. Additionally, because the antennas are rotating, the radiation source must be on for a sufficient time to allow the antennas to be positioned in the desirable orientation. This places a fairly high demand on the antenna positioning system.

What is needed then is an object locating system which can be used for locating a gaming ball and which in one application utilizes the slow speed of sound waves, but does not suffer the environmental drawbacks associated with the prior art devices, or in an alternate application utilizes radio frequency technology in an effective manner. It is therefore an object of the present invention to provide these systems.

SUMMARY OF THE INVENTION

This invention discloses object locator systems having a particular use for locating a gaming ball relative to a playing field. In one preferred ultrasonic embodiment, a locating system includes a calibration source on one side of the playing field, a number of sensing modules on an opposite side of the field, and a portable ultrasonic ball marking unit positionable on the field at the ball's location. The calibration source includes an ultrasonic transducer for emitting an ultrasonic sound wave at a particular sonic frequency and a radio frequency receiving circuit for receiving a radio frequency signal. The portable ball marking unit includes an ultrasonic trans-

ducer for emitting an ultrasonic sound wave at substantially the same frequency as the calibration source and a radio frequency source for emitting a radio frequency signal for switching the calibration source off during ball marking procedures. The sensing modules include ultrasonic receivers for receiving the ultrasonic signals from both the calibration source and the ball marking unit. A processing unit processes the signals sensed by the module sensors.

In operation, the calibration source continuously emits an ultrasonic signal which is received by the sensor modules. The sensing modules in turn convert the ultrasonic signal to proportionate electrical signals and send the electrical signals to the processing unit. A time delay is administered to the electrical signals such that the processing unit perceives the ultrasonic signal to have been received by a reference sensor first such that the signals received by the other sensors are referenced relative to the reference sensor. Each of the electrical signals from the sensing modules are processed by the processing unit to measure their relative time difference in order to calibrate the system to the instantaneous environmental conditions.

When a gaming official wishes to determine the ball's location, he places the ball marking unit at the location of the ball and activates it. The ball marking unit then emits an ultrasonic frequency to the sensing modules and a radio frequency signal to the calibration source and the sensing modules. The radio frequency signal causes the calibration source to switch itself off such that the only ultrasonic signal that the sensing modules receive is from the ball marking unit. The processing unit receives the signals from the sensing modules and determines the ball marking unit's location through a delay time acquisition process, taking into consideration adjustments for environmental conditions as previously calculated by the signal from the calibration source.

In an alternate radio frequency (RF) embodiment, a number of RF receivers are positioned relative to the playing field. A portable ball marking unit is positionable on the field and when activated sends an RF signal to be received by each of the RF receivers. As above, a reference receiver always receives the RF signal first. The signal from the reference receiver is then applied to a series of programmable delay circuits which incrementally delay the received signal a predetermined amount. The delayed signal is separately compared to the signals from the other receivers in threshold logic circuits, and an output of the threshold logic circuits is applied to the programmable delay circuits for sending a signal indicative of when the signal from the reference receiver has been delayed enough to match in time the signals from the other receivers. When the delay times between the reference receiver and each of the other receivers have been determined, these delay times are compared by a processing unit to determine the position of the gaming ball by a delay time acquisition process. If desirable, a set of additional receivers can be incorporated in order to derive a vertical position of the object to be located.

The delay time acquisition process compares the different time delays in order to determine the position of the ball. The process maps the playing field into two sets of elliptical cylindrical coordinates centered midway between the location of the reference receiver and either of the other receivers. By determining along which coordinate ray of each coordinate system the received signal is being generated, and then tracing these coordinate rays out from the sideline position, it is possible to determine the convergence of the rays, and thus the location of the portable ball marking unit, which indicates the ball's location within a minimum tolerance.

The systems discussed above may include an automatic ball marker and first down marker fixed to a drive chain running the length of the field for providing a visual reference of the football location and the down. In this manner, the processing unit associated with the systems is connected to the driving devices which drive the chains connected to the first down marker and ball marker. Consequently, not only can the system determine the ball's position, but also can automatically provide a visual display of this location. Additional objects, advantages, and features of the present invention will become apparent from the following description and the appended claims, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustration of a playing field incorporating a ball locating system according to preferred embodiments of the present invention;

FIG. **2** is a signal processing unit which processes ultrasonic and radio frequency signals as a part of the ball locating system;

FIG. **3** is a portable ball marking unit according to a preferred embodiment of the present invention;

FIG. **4** is a sensing module according to a preferred embodiment of the present invention;

FIG. **5** is a calibration source according to a preferred embodiment of the present invention;

FIG. **6**(*a*) is a schematic block diagram of an object locating system according to another preferred embodiment of the present invention;

FIG. **6**(*b*) is a receiver position depiction of receivers of the system of FIG. **6**(*a*);

FIG. **6**(*c*) is a circuit diagram of one of the threshold logic elements of FIG. **6**(*a*);

FIG. **7** is a graphic representation of the playing field of FIG. **1**;

FIGS. **8**(*a*)–**8**(*b*) are coordinate axes depictions of the playing field of FIG. **1**;

FIG. **9** is a representation of a ray convergence process for locating a position relative to the playing field of FIG. **1**;

FIG. **10** is a flow chart showing the steps of a ball location process according to one preferred embodiment of the present invention;

FIG. **11** is a side view of an automatic ball marking system as depicted in FIG. **1**;

FIG. **12** is a cut-away side view of a portion of the ball marking system of FIG. **11**;

FIG. **13** is a cut-away side view of a second portion of the ball marking system of FIG. **11**;

FIG. **14** is a cut-away end view of a third portion of the ball marking system of FIG. **11**; and

FIG. **15** is a cut-away side view of a ball marker.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following discussion of the preferred embodiments concerning ball locating systems and procedures is merely exemplary in nature and is in no way intended to limit the invention or its application or uses.

The discussion of the locating systems of the present invention will be given with particular reference to the

location of a football, but it should be understood that the system is adaptable to other games and sports, as well as other non-gaming applications such as security systems, geophysical services, military, and virtual reality, without departing from the spirit and scope of the invention.

With this in mind, first refer to FIG. 1 in which a football playing field 10 is shown. The playing field 10 includes a first side line 12, a second opposite side line 14, a first end zone region 16 and a second opposite end zone region 18. Further, a first goal post target 20 is shown relative to the end zone 16 and a second goal post 22 is shown relative to the end zone 18.

Incorporated in association with the playing field 10 is a ball marking system 15 for automatically providing a visible representation of the football's location and the appropriate down and first down distance. As will be discussed in greater detail below with particular reference to FIG. 11, the ball marking system 15 includes a first control unit 17 connected to one end of a segmented aluminum track drive 19 and a second control unit 21 connected to the opposite end of the track drive 19. A pair of drive chains traveling through the track drive 19 between the control units 17 and 21 position a ball marker 23 and a first down marker 25.

Also incorporated in association with the playing field 10 is a ball locating system according to one preferred embodiment of the present invention. The ball locating system includes a calibration source 24 positioned a predetermined distance from the side line 12 and three ultrasonic module sensors 26, 28 and 30 positioned at predetermined locations relative to the opposite side line 14, as shown. The calibration source 24 is operable to emit an ultrasonic frequency signal at a particular frequency f_1 and the sensing modules are operable to receive this signal, as will be discussed in greater detail below. Additionally, a ball marking unit 32 is positioned at a specific location on the playing field 10 relative to the position of a football (not shown) and is portable such that it can be moved to alternate locations on the field 10. The portable ball marking unit 32 is operable to transmit an ultrasonic frequency substantially at the same frequency f_1 as the calibration source 24 emits its ultrasonic frequency, and a radio frequency signal at a second frequency f_2 in order to instruct the calibration source 24 to discontinue emitting its signal. A signal processing unit 34 is incorporated to receive electrical signals from the module sensors 26, 28 and 30 and process these signals to produce delay signals. The delay signals are then sent to a central processing unit (CPU) 36 for performing time acquisition computations on the signals for determining the position of the football. Alternatively, the processing unit 34 and the CPU 36 can be a single device.

Turning to FIG. 2, each of the ultrasonic sensing modules 26, 28 and 30 is shown electrically connected to the signal processing unit 34 by means of a series of velocity-compensated coaxial cables 40, 42 and 44, respectively. As mentioned above, each of the sensing modules 26, 28 and 30 receives the ultrasonic signal f_1 whether it is coming from the calibration source 24 or the portable ball marking unit 32. Once the sensing modules 26, 28 and 30 convert the acoustical energy into electrical energy, they transfer the electrical signal to the processing unit 34 by the coaxial cables 40, 42 and 44. The application of the electrical signals to the coaxial cables 40, 42 and 44 is such that electrical signals from the modules 26 and 30 do not reach the processing unit 34 before the signal from the module 28. In this manner, the sensor module 28 acts as a reference module and it is the comparison of the difference between the delay time of the signal received at the module 26 and the module 28, and the delay time between the signal received at the module 30 and the module 28 which is analyzed to determine the ball's location.

In the processing unit 34, the coaxial cable 40 is electrically connected to a first limiter circuit 46, the coaxial cable 42 is electrically connected to a second limiter circuit 48, and the third coaxial cable 44 is electrically connected to a third limiter circuit 50 in order to filter the electrical signals and achieve greater noise immunity. The outputs from each of the limiter circuits 46, 48 and 50 are then applied to three separate threshold detection circuits 52, 54, and 56, respectively, as shown. The threshold detection circuits 52, 54, and 56 apply a minimum threshold comparison to the electrical signals from the sensing modules 26, 28 and 30 in order to provide a minimum signal level to reduce the probability of detecting false signals. The outputs from each of the threshold detection circuits 52, 54 and 56 are then applied to the central processing unit 36 as interrupt signals 58, 60 and 62, respectively. The CPU 36 measures the relative time difference between the difference of the signals received at the modules 26 and 28 and the difference of the signals received at the modules 30 and 28, and performs computations to determine the ball's position as will be discussed in greater detail below.

The signal processing unit 34 also receives the radio frequency f_2 from the portable ball marking unit 32 by an antenna 64 so that the processing unit 34 knows if it is receiving signals emitted by the calibration source 24 or the portable ball marking unit 32. The antenna 64 transmits the received radio frequency signal f_2 to an on-channel receiver 66. The output of the receiver 66 is applied to a demodulation circuit 68 to provide interrupt signal 70 indicating whether the ball marking unit 32 is active and, depending on which directional button (discussed below) was pressed on the ball marking unit 32, provides interrupt information on whether the game activities are directed toward the goal 20 or the goal 22 on output lines 72 and 74. Interrupt output 75 provides CPU 36 with an indication that ball marking unit 32 is in a relocate or reposition mode of operation, wherein the user is attempting to determine a previously calculated position of the ball. Additionally, the signal processing unit 34 includes an astable multivibrator 76 for generating a clocking frequency applied to the central processing unit 36 as a timing reference to be used with the locating method to be discussed below.

Signal processing unit 34 additionally includes rf signal generator 63 receiving signal generating inputs 65,67 and 69 from CPU 36 and having a modulated output with carrier frequency f_3 coupled to radiating antenna 61. As will be explained in greater detail below, when a RELOCATE or REPOSITION switch on ball marking unit 32 is activated, CPU 36 enters a mode wherein a currently calculated position of unit 32 is compared to the last previously determined position of the ball. The location of unit 32 relative to the last ball location is then indicated to unit 32 via LEFT, RIGHT or IN-POSITION signals on leads 65, 67 and 69. Such signals are then transmitted to ball locator unit 32 via signal generator 63 and antenna 61.

Now turning to FIG. 3, the details of the portable ball marking unit 32 will be discussed. The portable ball marking unit 32 is shown positioned relative to the

playing field 10 such that a tuned port 80 associated with the unit 32 is a known, desirable distance 82 above the surface of the playing field 10. The ball marking unit 32 includes a housing 84 for enclosing the different components associated with the unit 32 and a wrist strap 86 so that the gaming official can easily carry and hold the unit 32. The tuned port 80 is a molded cavity within the housing 84.

The ball marking unit 32 is powered by a rechargeable battery pack 88. Power is applied from the battery pack 88 to a signal generator 90 which is coupled to an ultrasonic transducer 92. The ultrasonic transducer 92 is coupled to the air through the tuned port 80. The tuned port 80 increases the coupling efficiency to the air at the desirable height 82 in order to increase the reliability of transmitting and receiving the ultrasonic signal f_1. The battery pack 88 additionally applies power to an on-channel radio frequency transmitter 94 and a modulator heterodyne 96. The modulator heterodyne 96 includes a first button switch 98 and a second button switch 100 such that the gaming official will press one of the two buttons to transmit an RF signal indicating toward which goal the game is being played. Depending on which of two button switches 98 or 100 is pressed, one of two tones will be placed on a carrier wave generated in the transmitter 94 and will be transmitted through an antenna 102 embedded in the housing 84. Additionally, if switch 99 is activated, a third signal will be transmitted via modulator heterodyne unit 96 and antenna 102 for receipt by signal processing unit 34 as an indication that unit 32 is being operated in a RELOCATE OR REPOSITION mode.

In a football game application, the RELOCATE mode would be used by the official to reset the ball at its location on a previous down, for example, after an incomplete forward pass or in preparation for adding penalty yardage from the previous position of the ball. In the RELOCATE mode the official would move unit 32 along the field and wait for the in position light (IPD) 97 to visually indicate the previous position has been attained. The official knows which direction in which to move unit 32 by observing the left and right arrow lamps 93 and 95. The left, right and in-position lamps are activated by signals transmitted by signal processing unit 34 (FIG. 2) and received at unit 32 via antenna 91 and demodulator unit 89. Alternatively, audible indications could be given to the user of unit 32. In the normal, non-relocate mode, the IPD lamp or audible signal is also used to indicate to unit 32 from CPU 36 that the calculation of a new ball position is complete.

The RELOCATE mode could find non-gaming object location applications. For example, in underwater salvage operations, one could accurately return to the last inspected search location after an interruption in salvage or search activity.

Now turning to FIG. 4, a discussion of one of the sensor modules 26 will be given. It will be understood that both of the other sensor modules 28 and 30 will be identical to the sensor module 26 of FIG. 4, and therefore will not be discussed. The sensor module 26 includes a housing 112 which is buried in the ground relative to the side line 14 of the playing field 10 such that a portion 106 of the housing 112 extends a predetermined distance above the ground. Molded as part of the housing 112 within the portion 106 is a tuned port 108. The module sensor 26 includes a transducer, such as a microphone, element 110 acoustically connected to the tuned port 108. The microphone element 110 converts the acoustical energy received by the port 108 to electrical energy variable at an ultrasonic rate. This electrical signal is then applied to a band-pass amplifier 114 to achieve greater selectivity and generate enough energy to drive the coaxial cable 44. The band pass filter 114 is powered by a DC signal coming through the cable 44 from the signal processing unit 34.

Now turning to FIG. 5, a discussion of the calibration source 24 will be given. As is apparent, the calibration source 24 is substantially identical to the sensor module 26 in appearance. In this regard, the calibration module 24 includes a housing 124 embedded in the ground relative to the side line 12 of the playing field 10 such that a portion 120 of the housing 124 extends above the ground so that a tuned ultrasonic port 122 is positioned the distance 82 above the ground. As above, the tuned port 122 is molded as part of the housing 124. Additionally, the tuned port 122 is acoustically connected to a transducer 126. The transducer 126 is electrically connected to signal generator 128 for generating an electrical driving signal to transducer 126 which, in turn, generates the acoustic signal. The signal generator 128 receives power from a rechargeable battery pack 130 and also a signal from a receiver 132. The receiver 132 generates the shut-off signal to generator 128 when an antenna 134 receives the radio frequency f_2 from the ball marking unit 32. Additionally, a shut-off switch (not shown) can be incorporated to turn the calibration source 24 off when the ball locating system is not in operation.

Now turning to FIG. 6(*a*), a ball locating system 160, according to a second preferred embodiment of the present invention, is shown in a schematic block diagram. In this embodiment, only radio frequency signals will be utilized as the transmission between a ball marking unit (not shown) and the different receivers positioned relative to the playing field 10. Because RF signals are used, the environment does not play a factor in transmission, and therefore, a calibration source is not required. For simplicity, the ball marking unit and the receivers can be configured in the same positions relative to the playing field 10 as discussed above for the ball marking unit 34 and the sensor modules 26, 28 and 30. Further, because the ball marking unit associated with this embodiment is a simple RF transmitter, well known to those skilled in the art, it need not be depicted. Likewise, since each of the receivers in this embodiment are simple RF receivers which convert RF energy into proportionate electrical signals, these receivers are also well known in the art, and therefore, will not be elaborated on in any further detail.

The system 160 includes a first receiver 162 and an associated RF antenna 164, a second receiver 166 and an associated RF antenna 168, a third receiver 170 and an associated RF antenna 172, a fourth receiver 174 and an associated RF antenna 176, and a fifth receiver 178 and an associated RF antenna 180. Turning to FIG. 6(*b*), one possible configuration of the receivers 162, 166, 170, 174 and 178 is shown relative to each other. It is noted, however, with the RF embodiment, the configuration of the receivers 162, 166, 170, 174 and 178 relative to the playing field 10 can be arbitrary. The configuration of the receivers relative to each other should, however, be arranged such that there is a horizontal configuration of the receivers 162, 166 and 170 and a vertical configuration of the receivers 166, 174 and 178. The dashed line represents an arbitrary zero. In

this manner, the receiver 166 acts as a reference receiver for the horizontal configuration and the receiver 174 acts as a reference receiver for the vertical configuration. All of the horizontal signals are processed relative to a signal received first at the receiver 166, and all of the vertical signals are processed relative to a signal received first at the receiver 174. Although the system 160 can be used in a variety of object locating systems, it is stressed that for a football locating application, only the receivers 162, 166 and 170 are required as with the first embodiment above.

Returning to FIG. 6(*a*), the signals received by each of the antennas 164, 168, 172, 176 and 180 are processed by the associated receivers 162, 166, 170, 174 and 178 to produce a clipped, hard-limited square wave having frequency f_1. The output signal from the reference receiver 166 is separated and applied to a first coarse programmable delay circuit 182 and a second coarse programmable delay circuit 184. The programmable delay circuits 182 and 184 provide a coarse delay used in determining the delay times of received signals. The signals from the programmable delay circuits 182 and 184 are then applied to first and second fine programmable delay circuits 186 and 188, as shown. If smaller time delay measurements are desired, then additional delay circuits can be cascaded to further increase the delay resolution. The outputs from the fine programmable delay circuits 186 and 188 are applied to threshold logic circuits 190 and 192, respectively. Additionally, the signal from the sensor 162 is applied to the threshold logic circuit 190, and the signal from the sensor 170 is applied to the threshold logic circuit 192. The output from each of the threshold logic circuits 190 and 192 is applied to inhibit further incrementing of the first and second programmable delay circuits 182, 186 and 184, 188, respectively. Delay times from the delay circuits 182, 186 and 184, 188 are then applied to a CPU (not shown) for comparison as will be discussed in greater detail below. The programmable circuits 182–186 are commercially available microcomputer controlled devices well understood to those skilled in the art. Circuits 182–186 could, for example, comprise type AD9500 available from Analog Devices.

Threshold logic elements 190,192,202 and 204 are circuits which respond quickly to inputs of very short duration pulses of varying phase. The desired output of the threshold logic element is activated only when the two inputs thereto are substantially exactly in phase. Each threshold logic element 190,192,202 and 204 could, for example, be comprised of three commercially available ultra fast operational amplifiers configured as shown in FIG. 6*c*. One such suitable device for each operational amplifier is the LH0032 from National Semiconductor. Threshold logic element 190 of FIG. 6*a* is set forth in more detail in FIG. 6*c*. Inputs 191 and 193 and output 195 are shown in both FIGS. 6*a* and 6*c*.

As mentioned above for the ultrasonic embodiment, the signal processed by the reference receiver 166 is always physically received prior to the signals received at receivers 162 and 170. This signal is processed through the programmable delay circuits 182–188 in order to delay the pulsed signal a complementary time so as to coincide with the signals received at the other two receiver modules 162 and 170. As long as the operating signal frequency is lower than approximately 3.0 MHz, the leading edge of one cycle will not overlap the leading edge of the next cycle in the worst-case transit time, thus eliminating the possibility of aliasing. The programmable delay circuits 182 and 186 provide a high resolution in incremental steps of delay for the pulsed signal received at their inputs. The output from the fine programmable delay circuit 186 is applied to the threshold logic circuit 190 along with the signal from the receiver 162 for comparison of the two signals. When the signal from the receiver 166 has been delayed enough so that the two signals from receivers 162 and 166 coincide, the signal at the output of the threshold logic circuit 190 applied to the fine programmable delay circuits 182, 186 will indicate that this event has occurred, and the delay circuit will output a delay signal indicative of the delay. The delay time between the signals of receivers 162 and 166 is immediately determined by reading a digital output word of the microprocessor used to program the delay circuits. Additionally, the time delay between the signals of receivers 166 and 170 may be read as a digital output word the microprocessor applied to the programmable delay circuits 184, 188.

The signal from the vertical reference receiver 174 is also applied to a third programmable coarse delay circuit 194 and a fourth programmable coarse delay circuit 196 to provide for vertical delay comparison. The outputs from the programmable delay circuits 194 and 196 are applied to fine programmable delay circuits 198 and 200, respectively. The outputs from the programmable delay circuits 198 and 200 are applied to threshold logic circuits 202 and 204, respectively. Additionally, the signal from the horizontal reference receiver 166 is applied to the threshold logic circuit 202 and the signal from the vertical receiver 178 is applied to the threshold logic circuit 204. The outputs from the threshold logic circuits 202 and 204 are applied to the programmable delay circuits 194, 198 and 196, 200, respectively. In this manner, delay times are generated as the inputs to the delay circuits 194, 198 and 196, 200 for the vertical direction in the same manner as above for the horizontal direction. These delay signals are then applied by the CPU to the programmable delay circuits in the same manner as discussed above. The combination of the vertical and horizontal location provides a method of locating an object in a three-dimensional space.

A discussion of the calculations to be performed, according to a preferred embodiment, in order to attain the acquisition of time delays for determining the position of the gaming ball (or other object) for both embodiments above will now be given. Referring to FIG. 7, the playing field 10 is shown relative to a coordinate axis system. The length of the field is the x-axis and the width of the field is the y-axis, both represented in inches. According to the sensor configuration in FIG. 1, the sensing module 26 will be at the $x=0$ inch line, the sensing module 28 will be at the $x=1800$ inch line, and the sensing module 30 will be at the $x=3600$ inch line. The receivers for the RF embodiment can also take on this configuration. Therefore, the discussion below will be equally relevant to that embodiment and as such sensing modules 26, 28 and 30 will be interchangeable with receivers 162, 166 and 170, respectively.

As mentioned above, the sensing module 28 receives the ultrasonic signal first, and thus, acts as a reference for the delay signals as received and sent by the sensing modules 26 and 30. It has been discovered that the delay time between the reference signal received directly at the sensing module 28 and the signal received at the sensing module 28 via the sensing module 26 can be depicted as an elliptical cylindrical coordinate system

with the y-axis centered at the x=900 inch line as represented in FIG. 8(*a*). Likewise, the delay time between the reference signal received directly at the sensing module **28** and the signal received at the sensing module **28** via the sensing module **30** also can be depicted as a second elliptical cylindrical coordinate system with the y-axis centered at the x=2700 inch line as shown in FIG. 8(*b*).

Therefore, each delay time can be represented as one of the rays of the elliptic cylindrical coordinate system associated with each of the sensing modules **26** and **30** depending on the location of the ball marking unit **32**. Once it is determined which ray of each coordinate system is representative of the delay time, the two rays can be traced out from the horizontal reference axes of the coordinate systems until they converge within a predetermined tolerance. This converging point is the location of the ball marking unit **32**. This concept is graphically depicted in FIG. **9**. In this figure, U1 and U2 represent variable locations along each ray being traced out. More particularly, U1 represents incremental positions along the particular ray being traced from the coordinate system of the sensing module **26**, and U2 represents incremental positions of the ray being traced out from the sensing module **30**. U1 and U2 have a value of zero (0) at the sideline **14**.

With the discussion above concerning ray tracing, the method of actually calculating the gaming ball's position will be given with particular reference to the flow chart as shown in FIGS. **10***a* and **10***b*. In FIG. **10***a*, block **220** represents the continuous calculation of a correction factor provided by the calibration source **24** and as performed by the CPU **36**. A correction factor is calculated for each of the different delay times for the sensing modules **26** and **30**. More particularly, the correction factor CF1 for the sensing module **26** and the correction factor CF2 for the sensing module **30** are represented by the following equations:

$$CF1 = (\sqrt{LA^2 + WA^2} + 1800 - \sqrt{(1800 - LA)^2 + WA^2})/PC1,$$

$$CF2 = (\sqrt{(3600 - LA)^2 + WA^2} + 1800 - \sqrt{(1800 - LA)^2 + WA^2})/PC2,$$

where LA is the x-axis position of the calibration source **24**, WA is the y-axis position of the calibration source **24**, PC1 is the measured pulse count between the direct reception of the ultrasonic signal at the sensor module **28** and the ultrasonic signal received at the sensor module **28** via the sensor module **26**, and PC2 is the measured pulse count between the direct reception of the ultrasonic signal from the calibration source **24** at the sensor module **28** and the ultrasonic signal received at the sensor module **28** via the sensor module **30**. The correction values CF1 and CF2 are given in inches per pulse and are continuously updated when the system is on. Because the RF embodiment does not require calibration, this step is not performed for the RF embodiment.

If the ball marking unit **32** is switched on as represented by decision block **222**, the sensing modules **26**, **28**, and **30** will then receive the ultrasonic signal from the ball marking unit **32**. The delay times are measured as values P1 and P2, where P1 is the measured pulse count between the direct reception of the ultrasonic signal from the ball marking unit **32** at the sensor module **28** and reception of the signal at the sensor module **28** via the sensor module **26**, and P2 is the measured pulse count between the direct reception of the ultrasonic signal from the ball marking unit **32** at the sensor module **28** and reception of the signal at the sensor module **28** via the sensor module **30**. Once the delay times P1 and P2 are calculated, they are corrected (in the ultrasonic embodiment) by multiplying the correction factor CF1 times the delay value P1 and the correction factor CF2 times the delay value P2 in order to get corrected delay values D1 and D2, respectively. This step is represented by box **224**. For the RF embodiment, the system does not calculate corrected delay values, but merely uses P1 and P2 (converted to units of length, or in this rf embodiment, inches).

As is known from classical mathematics (see, for example, *Schaum's Outline Series—Mathematical Handbook of Formulas and Tables*, M. R. Spiegel 1968), in an elliptical cylindrical coordinate system having coordinates u, v, z, the traces of these coordinate surfaces on the xy cartesian coordinate plane are given by

$x = a(\cosh u)(\cos v)$

$y = a(\sinh u)(\sin v)$

where $u \geqq o$ and $o \leqq v \leqq 2\pi$

A parabolic path or ray is defined for each value of v (where v is the angle a tangent to the ray makes with the x axis), and as one proceeds from the x axis (u =o) outwardly along each ray, u increases as a series of ellipses. Therefore, to determine which ray represents a delay time D at starting point u =o in FIGS. 8(*a*), and 8(*b*), a sine and cosine calculation for each of the delay times is performed. This step is represented by block **226**. The cosine value CV1 for the coordinate system of the sensing module **26** is given by the equation:

$$CV1 = (D1 - 1800)/1800.$$

The sine value SV1 for the coordinate system of the sensing module **26** is given by the equation:

$$SV1 = +\sqrt{1 - (CV1)^2}.$$

Likewise, the cosine value CV2 for the coordinate system of the sensing module **30** is given by the equation:

$$CV2 = (1800 - D2)1800.$$

And finally, the sine value SV2 for the coordinate system of the sensing module **30** is given by the equation:

$$SV2 = +\sqrt{1 - (CV2)^2}.$$

Once these calculations are made and the specific rays to be traced are distinguished, it is necessary to iteratively proceed along both of the delay rays until they converge within a predetermined tolerance as discussed above with respect to FIG. **9**. As represented by the step of block **228**, the CPU **36** first initializes U1 and U2 to zero (0) as representative of the values of U1 and U2 at the sideline **14**. Next, as represented by the step of block **230**, the values of U1 and U2 are incremented a predetermined amount. Once the new values of U1 and U2 are available, values X1, Y1, X2 and Y2 are calculated as possible ball locations along the partic-

ular ray for each of the coordinate systems as represented by the following equations:

$$X1=900\times COSH(U1)\times CV1+900,$$

$$Y1=900\times SINH(U1)\times SV1,$$

$$X2=900\times COSH(U2)\times CV2+2700, \text{ and}$$

$$Y2=900\times SINH(U2)\times SV2.$$

In other words, (X1, Y1) represents the cartesian coordinate value of U1, and (X2, Y2) represents the cartesian coordinate value of U2. This is represented by the step of block 232. The distance between the two calculated values for the possible ball locations is then determined at block 234 by the following equation:

$$\text{DISTANCE} = \sqrt{(X2-X1)^2+(Y2-Y1)^2}\ .$$

If this distance is within a predetermined tolerance as represented by the step of decision block 236, then the CPU 36 will, at decision block 221 of FIG. 10*b*, determine whether ball marker unit 32 is in normal or relocate operating mode. If in normal mode, CPU 36 will indicate the position of the ball, set markers, etc., as indicated at block 238. This new ball position is also saved at block 239. When the points (X_1, Y_1) and (X_2, Y_2) are within tolerance, the displayed and stored position can be chosen as either of the cartesian coordinate pairs. Alternatively, and X and Y value could be interpolated from the pairs. Obviously, in the case of football yardage marking, only an X coordinate need be determined. If, however, the distance is not within the predetermined tolerance, the procedure will return to the step 230 of FIG. 10*a* for incrementing and/or decrementing the values of U1 and U2 by a predetermined amount in order to recalculate their position relative to the rays being traced to find the convergence of the two rays. It has been shown in practice that this method of calculation has an upward maximum value of about 25 steps. In this manner, an accurate location of a gaming ball can be calculated in an effective manner.

Returning to the flow chart of FIG. 10*b*, if ball marking unit 32 is in the relocate mode, as determined by decision block 221, then CPU 36 compares the just-calculated position with the last previous position at block 223. If the current position of unit 32 is to the left of the last position, as determined at decision block 225, then a LEFT or L signal is forwarded to unit 32. If the current position of unit 32 is to the right of the last position, as determined at decision block 229, then a RIGHT or R signal is forwarded to unit 32. If the old and new positions coincide (within a preselected tolerance), then an in-position-detected, or IPD, signal is forwarded to unit 32. Of course, it will be appreciated that in a football game application, only the X-axis component of the position of unit 32 need be examined at blocks 223, 225 and 229 of FIG. 10*b*. In other two or three dimensional relocate applications, coincidence of all coordinate locations would be required.

Now turning to FIG. 11, a side view of the ball marking system 15, discussed above with reference to FIG. 1, is shown. As mentioned above, the ball marking system 15 includes the first control unit 17 at one end of the playing field 10 and the second control unit 21 at an opposite end where a segmented aluminum drive track 19 connects the units 17 and 21. The control units 17 and 21 are operable to position a set of chain drives travelling through the drive track 19 so as to position the ball marker 23 and a first down marker 25 anywhere along the playing field 10 for a visual representation of the football location and the distance to a first down.

FIG. 12 depicts a cut-away side view of the control unit 17 of the system 15. Positioned within the unit 17, in one embodiment, is a processing unit 262, which could be the CPU 36 of FIG. 1, electrically connected to a ball marker drive unit 250 and a first down marker drive unit 252. The processing unit 262 receives its commands from a transducer interface 254 which, in turn, receives its signal from a series of coaxial cables 256 connecting the interface 254 with the sensors depending on the ball locating system used in association with the system 15.

The ball marker drive unit 250 is connected to a first drive chain 258 in order to position the ball marker 23 at any location along the field 10. Additionally, the first down marker drive unit 252 is connected to a second drive chain 260 in order to position the first down marker 25 at any location along the field 10. A series of drive pulleys provide the connection mechanisms between the drive chains and drive units, as shown. When the ball marker drive unit 250 and the first down marker drive unit 252 receive control signals from the processing unit 262, they automatically position the ball marker 23 and the first down marker 25 by means of the drive chain 258 and 260 accordingly. Therefore, once the processing unit processes the delay signals from the sensors it automatically positions the ball and first down markers 23 and 25.

The ball marker 23 is connected to the drive chain 258 by means of a marker support assembly 266, which will be described in greater detail below. Furthermore, a breakaway section 264 is incorporated at the base of the ball marker 23 adjacent the support assembly 266. The breakaway section 264 provides a means by which the ball marker unit 23 will give away in order to avoid personal injury if contacted by a player.

Turning to FIG. 13, the control unit 21 is shown in a cut-away side view. The control unit 21 includes a first chain drive unit 268 for adjusting chain slack and expansion characteristics of the drive chain 260 and a second chain drive unit 270 for adjusting chain slack and expansion characteristics of the drive chain 258. The chain drive units 268 and 270 are commercially available units, such as the DC1 VS product line available from Reliance Electric, or other equivalent unit wherein electronic monitoring of the chain drive motor speed and torque provides feedback information for maintaining consistent control of the drive chain, while preventing chain breakage and enabling exact positioning thereof. The drive chains 258 and 260 are connected to the chain drive units 268 and 270 by means of associated pulleys, as shown. As mentioned above, the segmented aluminum drive track 19 connects the control unit 17 with the control unit 21 along which the drive chains 258 and 260 travel.

Turning to FIG. 14, a cross-sectional end view of the aluminum drive track 19 is shown. As is apparent, the ball marker 23 and the first down marker 25 are connected to the drive chains 260 and 258, respectively, within the drive track 19. A series of nylon guides 272 enable the drive chains 258 and 260 to travel through the drive track 19 with the appropriate and desirable support with minimization of friction. Additionally, a series of nylon bushing assemblies 274 known to those

skilled in the art, are attached to the drive chains **258** and **260** at predetermined locations.

FIG. **15** shows a cut-away side view of the ball marker **23**. It will be understood that the first down marker **25** is identical, and the discussion below will equally apply to that marker. The ball marker **23** engages the drive chain **260** by means of a spring-loaded locking mechanism **278**. The spring-loaded locking mechanism **278** includes a first plate **280** having downward protruding teeth **286** and a second plate **282** also having downward protruding teeth **288**. The first and second plates **280** and **282** are connected to each other by means of a spring **284**. In this manner, the drive chain **260** can engage with the teeth of the locking plates **280** and **282** in order to move the ball marker unit **23** along the drive track **19**.

The foregoing discussion discloses and describes merely exemplary embodiments of the present invention. One skilled in the art will readily recognize from such discussion, and from the accompanying drawings and claims, that various changes, modifications and variations can be made therein without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. An object locating system for locating a gaming ball relative to a playing field, said object locating system comprising:

a calibration source positionable relative to the playing field, said calibration source operable to emit an ultrasonic signal at a first frequency;

an object marking unit positionable relative to the playing field and relative to said gaming ball, said object marking unit operable to emit an ultrasonic signal at substantially the first frequency and a radio frequency signal at a second frequency, wherein the calibration source is further operable to receive the radio frequency signal from the object marking unit and discontinue emitting the ultrasonic signal upon receipt of the radio frequency signal;

a plurality of sensors positionable relative to the playing field, each of said sensors operable to receive the ultrasonic signal from either the calibration source or the object marking unit and convert the ultrasonic signal into a proportionate electrical signal; and

a processing unit operable to receive the electrical signals from each of the sensors and measure a time delay between ultrasonic signals received from at least two of the sensors.

2. The object locating system according to claim **1** wherein the calibration source includes a signal generator for generating an electrical signal, a transducer for receiving the electrical signal from the signal generator and generating a proportional ultrasonic signal, an antenna for receiving the radio frequency signal from the object marking unit and a receiver operable to switch off the signal generator upon receipt of the radio frequency signal.

3. The object locating system according to claim **1** wherein each of the plurality of sensors includes a transducer for receiving ultrasonic signals and generating a proportionate electrical signal to be transmitted to the processing unit.

4. The object locating system according to claim **1** wherein the processing unit includes a limiter circuit and a threshold detection circuit for each input from the plurality of sensors, each of the detection threshold circuits being operable to generate a time phased signal dependent on the ultrasonic signal received from the sensing modules, said processing unit further including an antenna for receiving the radio frequency signal and a demodulation circuit for providing an electrical signal related to the radio frequency signal.

5. The object locating system according to claim **1** wherein the object marking unit includes an ultrasonic generator for generating the ultrasonic signal, a modulator circuit for generating the radio frequency signal and an antenna for emitting the radio frequency signal.

6. The object locating system according to claim **1** wherein each of the object marking unit, the plurality of sensors and the calibration source include tuned ports operable to be positioned a predetermined distance above the preselected area.

7. The object locating system according to claim **1** wherein the processing unit is operable to receive the radio frequency signal in order to determine whether the signals are coming from the calibration source or the object marking unit.

8. The object locating system according to claim **1** wherein the plurality of sensors comprises three sensors positioned along a first boundary of the preselected area wherein one of the sensors is a reference sensor, and wherein the electrical signals from the sensors are applied to the processing unit so that the signal from the reference sensor reaches the processing unit before the signals from the other two sensors.

9. The object locating system according to claim **8** wherein the processing unit is operable to generate a first delay time as a function of the time that the signal from the reference sensor reaches the processing unit relative to when the signal from one of the other two sensors reaches the processing unit and a second delay time as a function of when the signal from the reference sensor reaches the processing unit and when the signal from the other of the two sensors reaches the processing unit.

10. The object locating system according to claim **9** wherein the processing unit is further operable to calculate a correction factor for each of the first and second delay times.

11. The object locating system according to claim **9** wherein the processing unit is further operable to calculate a location relative to the preselected area based on a comparison between first and second delay times.

12. An object locating system for locating a gaming ball relative to a playing field, said object locating system comprising:

a calibration source positionable relative to the playing field, said calibration source operable to emit an ultrasonic signal at a first frequency;

an object marking unit positionable relative to the playing field, said object marking unit operable to emit an ultrasonic signal at substantially the first frequency and a radio frequency signal at a second frequency, wherein the calibration source is further operable to receive the radio frequency signal from the object marking unit and discontinue emitting the ultrasonic signal upon receipt of the radio frequency signal;

a plurality of sensors positionable relative to the playing field, each of said sensors operable to receive the ultrasonic signal from either the calibration source or the object marking unit and convert the

ultrasonic signal into a proportionate electrical signal;

a processing unit operable to receive the electrical signals from each of the sensors and measure a time delay between ultrasonic signals received from at least two of the sensors; and

an automatic ball marking apparatus, said ball marking apparatus positionable adjacent the playing field and being operable to receive signals from the processing unit in order to automatically position a ball marker associated with the ball marking apparatus relative to the position of the gaming ball.

13. The ball locating system according to claim 12 wherein the ball marking apparatus includes a first control unit positionable proximate one end of the playing field, a second control nit positionable proximate an opposite end of the field, and a drive track extending between the first control unit and the second control unit, said first control unit including a drive unit operable to receive ball location signals from the processing unit and position a first drive chain upon receipt of the ball location signals, said first drive chain running through the drive track and being operable to position the ball marker.

14. The ball location system according to claim 13 wherein the first control unit includes a second drive unit operable to receive the ball location signals from the processing unit and position a second drive chain, said second drive chain also running through the drive track and being operable to position a down marker.

15. The ball location system according to claim 13 wherein the ball marker includes an elongated member extending from a support member wherein the support member is rigidly attached to the first drive chain, said elongated member including a breakaway section substantially adjacent to the support member.

16. A ball marking apparatus comprising:

a first control device positionable proximate one end of a playing field, said first control device including a drive unit operable to receive ball location signals from a processing unit and position a first drive chain upon receipt of the ball location signals;

a ball marker rigidly attached to the drive chain and being positionable upon movement of the drive chain in order to provide a visual representation of a ball location;

a second control device positionable proximate an opposite end of the field to the first control device, said second control device including a drive chain control unit operable to control the drive chain; and

a drive track extending between the first control device and a second control device, said drive track operable to house the drive chain.

17. The ball marking apparatus according to claim 16 wherein the ball marker includes an elongated member extending from a support member wherein the support member is rigidly attached to the first drive chain, said elongated member including a breakaway section substantially adjacent to the support member.

18. The ball marking apparatus according to claim 16 wherein the first control device includes a second drive unit operable to drive a second drive chain for positioning a down marker, said second drive unit also receiving ball location signals from the processing unit, said drive track further being operable to house the second drive chain between the first and second control devices.

19. The ball marking apparatus according to claim 16 wherein the first control device includes the processing unit and a transducer interface, said transducer interface operable to receive transducer signals from remote sensors and to send signals to the processing unit indicative of the signals from the sensors.

20. The ball marking apparatus according to claim 16 wherein the drive track includes a nylon bushing engageable with the drive chain for minimizing friction.

21. A locating system for locating a gaming ball relative to a playing field, comprising:

a transmitter positionable relative to said playing field and relative to said gaming ball having first means for transmitting a first signal at a first predetermined frequency;

a plurality of sensors positionable in a predetermined pattern relative to said playing field wherein one of the sensors is a reference sensor, each of the sensors operable to receive the first signal from the transmitter and produce a related electrical signal; and

a processing unit operable to receive and process each of the electrical signals from the plurality of sensors, said processing unit including a first delay circuit operable to delay the electrical signal received from the reference sensor to coincide with the electrical signal received from a first of the plurality of sensors and generate a first time delay signal representative of that delay, and a second delay circuit operable to delay the electrical signal received from the reference sensor to coincide with the electrical signal received from a second of the plurality of sensors and generate a second time delay signal representative of that delay, wherein the processing unit utilizes the first time delay signal and the second time delay signal to determine information relative to distances between the transmitter and the sensors.

22. The locating system of claim 21 wherein the first predetermined frequency is within the radio frequency spectrum.

23. The system according to claim 21 wherein the plurality of sensors includes a series of sensors for determining a horizontal location of the transmitter and a series of sensors for determining a vertical location of the transmitter, wherein the reference sensor is a horizontal reference sensor of the series of sensors for determining the horizontal location, and wherein the processing unit includes a third delay circuit operable to delay the electrical signal received from a vertical reference sensor to coincide with the electrical signal received from the horizontal reference sensor and generate a third time delay signal representative of that delay, and a fourth delay circuit operable to delay the electrical signal received from the vertical reference sensor to coincide with the electrical signal received from a third of the plurality of sensors and generate a fourth time delay signal representative of that delay, wherein the processing unit utilizes the third delay signal and the fourth delay signal to determine a vertical location of the transmitter.

24. The system according to claim 21 wherein each of the first and second delay circuits include a coarse delay circuit and a fine delay circuit for providing different levels of delay resolution.

25. The system according to claim 21 further comprising a first threshold detection logic circuit and a second threshold detection logic circuit, said first threshold detection logic circuit operable to receive the

electrical signal from the first sensor and an electrical signal from the first delay circuit and to provide an output signal to the first delay circuit indicative of the coincidence between the electrical signal from the first sensor and the electrical signal from the reference sensor, said second detection threshold logic circuit operable to receive the electrical signal from the third sensor and an electrical signal from the second delay circuit and to provide an output signal to the second delay circuit indicative of the coincidence between the electrical signal from the reference sensor and the electrical signal from the second sensor.

26. The system according to claim **21** wherein the first delay circuit and the second delay circuit are programmable.

27. The system according to claim **21** wherein the transmitter further comprises second means for transmitting at least one interrupt signal at a second frequency, and

wherein the processing unit further comprises interrupt signal receiving means operative to receive the at least one interrupt signal and to generate interrupt signals in accordance therewith.

28. The system according to claim **21** wherein the processing unit further comprises means for generating and transmitting an indication signal indicative that the location of the transmitter has been determined; and

wherein the transmitter further comprises indication signal receiving means for receiving the indication signal, and means for intelligibly indicating that the indication signal has been received.

29. The system according to claim **21** wherein the transmitter further comprises second means for transmitting the plurality of interrupt signals at a second frequency, and

wherein the processing unit further comprises interrupt signal receiving means operative to receive the plurality of interrupt signals and to generate interrupt signals in accordance therewith.

30. The system according to claim **21** wherein the processing unit further comprises means for transmitting at least one of a plurality of indication signals indicative of a location of the transmitter relative to a previously determined transmitter location; and

wherein the transmitter further comprises indication signal receiving means for receiving the at least one indication signal, and means for intelligibly indicating the location of the transmitter relative to the previously determined transmitter location.

31. A locating system for locating a game ball relative to a gaming field, comprising:

a transmitter having first means for transmitting a first signal at a first predetermined frequency, said transmitter operable to be positioned relative to the game ball on the gaming field;

three sensors positionable relative to the gaming field in a predetermined pattern wherein one of the sensors is a reference sensor, each of the sensors operable to receive the first signal from the transmitter and produce a related electrical signal, said reference sensor being positioned at a central location between the other two sensors; and

a processing unit operable to receive and process each of the electrical signals from the three sensors, said processing unit including a first delay circuit operable to delay the electrical signal received from the reference sensor to coincide with the electrical signal received from a first of the three sensors and generate a first time delay signal representative of that delay, and a second delay circuit operable to delay the electrical signal received from the reference sensor to coincide with the electrical signal received from a second of the three sensors and generate a second time delay signal representative of that delay, wherein the processing unit utilizes the first time delay signal and the second time delay signal to determine information relative to distances between the transmitter and the sensors.

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